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An Ecological Hazard Assessment for PCBs in the Spokane River

April 2001

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ECOLOGY

An Ecological Hazard Assessment for PCBs in the Spokane River

by
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Environmental Assessment Program
Olympia, Washington 98504-7710

April 2001

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Abstract

The Spokane River has the highest known PCB levels among Washington State rivers, lakes, and streams. In this report, the data on PCB concentrations in Spokane River fish, sediment, and water are summarized and reviewed, and an assessment is made of the ecological hazard for the river's aquatic life and fish-eating wildlife. Based on the available data and toxicological benchmarks used in the assessment, the primary ecological hazards identified were: 1) possible adverse effects on the sustainability of salmonid populations and fish-eating mammals, primarily in the reach between Trentwood and Nine-Mile Dam; and 2) possible adverse effects on benthic invertebrates in the Trentwood to Monroe Street Dam reach in areas where PCBs have been concentrated in fine-grained sediments, such as behind Upriver Dam. The ecological hazard due to the PCB levels in Long Lake and in the Spokane Arm is low. Fish-eating birds do not appear to be at risk in any part of the river.

Acknowledgements

This report benefited from review comments by John Roland of the Ecology Toxics Cleanup Program and Dale Norton and Nigel Blakley of the Ecology Environmental Assessment Program. Ecology and EPA staff at Manchester Environmental Laboratory analyzed most of the samples on which this assessment is based; their good work is appreciated. The final report was formatted by Joan LeTourneau.

Introduction

There has been longstanding concern about the levels of polychlorinated biphenyls (PCBs) in the Spokane River. The occurrence of elevated concentrations in the river's fish was first reported by the Washington State Department of Ecology (Ecology) in samples collected in 1980 (Hopkins et al., 1985). In that study, two composite whole fish samples from the Riverside Park area were found to have total PCB concentrations of 1,200 ug/Kg (parts per billion) and 230 ug/Kg, on a wet weight basis.

In the following years, Ecology analyzed over 200 fish tissue samples from the Spokane, all but two of which have had detectable concentrations of PCBs. As recently as 1999, total PCB concentrations greater than 1,000 ug/Kg have been measured in some species (Johnson, 2000a).

The Spokane River is currently on Ecology's 303(d) water quality limited list for not meeting EPA National Toxics Rule standards for PCBs in edible fish tissue. On March 7, 2001, the Washington State Department of Health issued a PCB advisory for people consuming Spokane River fish.

The purpose of the present report is to:

1) Provide general background information on PCB nomenclature, environmental fate, and effects to aquatic life.
2) Summarize the PCB data currently available for Spokane River fish, water, and sediment.
3) Provide a statewide and national perspective on the PCB levels observed in fish.
4) Assess the hazard PCBs pose to the river's aquatic life and fish-eating wildlife.

Because of the limited amount of Spokane River data appropriate for assessing ecological effects, only a partial assessment was possible.

This report was prepared in response to a request from the Ecology Eastern Regional Office, Toxics Cleanup Program.

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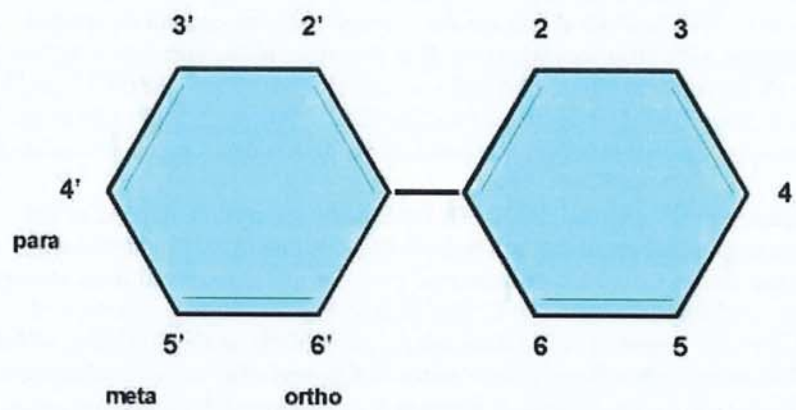
Background on PCBs[1]

PCBs are a family of chlorinated compounds with the general configuration shown in Figure 1. They share the basic structure of two six-carbon benzene rings (biphenyl) linked by a single carbon-carbon bond and can have up to 10 chlorine atoms, one attached to each available carbon atom. There are 209 PCB compounds possible depending on chlorine substitution patterns. The toxicity and persistence of PCBs is dependent not only on the number of chlorine atoms but also on whether the atoms are located at the ortho, meta, or para positions.



Structure of Polychlorinated Biphenyl (PCB) Molecule

Figure 1.

Individual PCB compounds are referred to as congeners. For example, 4,4'-dichlorobiphenyl is a congener with two chlorines, one on each of the two carbons at the para or outer positions on the two rings. PCB homologues are subcategories of PCB congeners having equal numbers of chlorine atoms. Tetrachlorobiphenyls, for example, are the PCB congeners with exactly 4 chlorine substituents, regardless of their arrangement.

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[1] Unless otherwise noted, this information was obtained from the following sources: Callahan et al. (1979); Eisler (1986); EPA (1992, 1993a, 1995a 1996, 2000a); EPA Region 5 (2001); Hammond et al. (1972); Kalmaz and Kalmaz (1979); McFarland and Clarke (1989); Peakall (1975); Schmitt et al. (1990); TAMS (2000); Tetra Tech (1992); and ThermoRetec (1999).

PCBs were first commercially produced in 1929. They were widely used in industrial applications as insulating fluids, plasticizer, in inks and carbonless paper, and as heat transfer and hydraulic fluids, but had a wide variety of other uses. After 1974 they were primarily used as insulating fluids in capacitors and transformers. EPA restricted manufacture of PCBs to sealed systems in 1977. In 1979 EPA banned PCB manufacture, processing, and distribution, but allowed continued use in closed electrical systems. EPA phased out use of electrical equipment containing PCBs through regulations in 1982 and 1985.

With few exceptions, PCBs were manufactured as complex mixtures of congeners, through progressive chlorination of batches of biphenyl. PCB mixtures have a range of physical/chemical properties and are designated by a numbering system based on chlorine content. The mixtures most commonly reported in environmental samples are PCB-1242, -1248, -1254, and -1260. The last two digits are the average chlorine content by weight (e.g., PCB-1254 averages 54% chlorine) while the first two refer to the number of carbon atoms in biphenyl. While PCBs were manufactured and sold under many names, in the United States the most common was the Aroclor series (e.g., Aroclor-1254). Approximately 150 of the 209 individual PCB compounds possible have been detected in the various Aroclor formulations.

Due to their persistence and widespread use, PCBs have been detected in all parts of the environment. Long-range transport in the atmosphere has resulted in PCB contamination of remote areas and is the reason for a PCB background in waterbodies removed from land-based sources. While their solubility in water is low, they sorb strongly to organic matter and sediments. PCBs have high potential to bioaccumulate, particularly in the fat (lipid) of fish and other organisms. Bioconcentration factors from water to fish and other aquatic organisms can be as high as 10^5. PCBs have been the subject of numerous environmental monitoring programs. Currently there are 38 states with fish consumption advisories for PCBs, more than for any other chemical contaminant.

A number of studies have documented a significant decrease in PCB levels in fish and other environmental media since the EPA ban. Between 1976 and 1984, mean PCB concentrations decreased in U.S. freshwater fish by approximately 60%. The rate of decrease appears to have slowed in the U.S. since the mid-1980s. In the Great Lakes it has been hypothesized that PCBs are reaching an equilibrium with external sources, but this is controversial (EPA, 1993b; Smith, 1995).

PCBs are generally not acutely toxic to aquatic biota in the natural environment. Lethal body burdens can be greater than 100,000 ug/Kg. Growth, molting, and reproduction are the primary functions shown to be affected in laboratory studies. PCBs can elicit a wide variety of responses in animals including wasting syndrome, hepatotoxicity, immunotoxicity, neurotoxicity, reproductive and developmental effects, gastrointestinal effects, respiratory effects, dermal toxicity, and mutagenic and carcinogenic effects.

Sensitivity to PCBs varies substantially between species. Aquatic and benthic invertebrates are less sensitive than higher animals. Because invertebrates lack the enzyme systems that react with dioxin-like PCBs they are not subject to the effects of dioxin-like PCBs (see below). Fish are most susceptible to PCBs in their early life stages, as a result of transfer from the female into

the eggs. PCBs have been implicated in declines of fish and wildlife populations such as Great Lakes lake trout and Columbia River mink. PCBs have also been linked to reproductive impairment of a number of fish-eating bird species.

Once released to the environment, PCB mixtures undergo alterations due to differential partitioning into air, water, and sediments, selective biodegradation and bioaccumulation, and mixing with PCBs from other sources. The PCB mixtures in water and air favor the less chlorinated congeners, which are more soluble and volatile. These are also more easily metabolized, and lower in persistence and toxicity. More highly chlorinated compounds persist absorbed to sediment, with the most highly chlorinated being bioaccumulated through the food chain. Because the higher chlorinated congeners are retained by biota, bioaccumulated PCBs appear to be more toxic than the commercial mixtures.

As a result of partitioning, transformation, and bioaccumulation, the PCB mixtures detected in most environmental samples do not resemble the commercial product. For example, in the Hudson River the predominant source of contamination is Aroclor-1242 from General Electric facilities. The PCB mixture in fish, however, resembles -1248 in the upper river, grading toward –1254 in the lower river, further from sources. The congener pattern in the Hudson's benthic invertebrates is intermediate between the sediments and the fish.

PCBs can be analyzed and reported as equivalent concentrations of commercial Aroclor mixtures, as homologues, or as individual congeners. Historically, most Spokane River samples have been analyzed for Aroclor-equivalents. For human health or ecological risk assessment, the U.S. Environmental Protection Agency (EPA) recommends summing the concentrations of Aroclor-equivalents to give total PCBs.

About half of the 209 possible congeners account for most of the environmental contamination from PCBs. Based on toxicity, prevalence, and relative abundance in animal tissues, the number of environmentally significant congeners is thought to be less than 40. Twenty-five of these account for 50-75% for the total PCBs in tissue samples of fish and other animals.

The PCB congeners of greatest environmental significance are substituted at the meta- and para-positions, with no ortho or some mono-ortho substitution. Here the phenyl rings assume a co-planar shape similar to 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDD or dioxin). The presence of two or more ortho-substituted chlorines causes the molecule to be non-coplanar, and these congeners do not produce a strong dioxin-like response. PCB congeners are commonly referred to by their IUPAC number (International Union of Pure and Applied Chemists). The three most potent congeners to fish are PCB-77 (3,3'4,4'-tetrachlorobiphenyl), PCB-81 (3,4,4',5-tetrachlorobiphenyl), and PCB-126 (3,3',4,4'5-pentachlorobiphenyl). The amount of congener data on the Spokane River is limited.

The toxicity of dioxin-like congeners can be expressed in terms of equivalent concentrations of 2,3,7,8-TCDD, referred to as Toxic Equivalents (TEQ). Each PCB congener is assigned a Toxicity Equivalency Factor (TEF) relative to TCDD. The TEF for TCDD is 1.0. A congener with 1/10 the toxicity of TCDD would have a TEF of 0.1. If its concentration in a fish tissue sample were 10 ug/Kg, the TEQ or equivalent concentration of TCDD would be 1 ug/Kg. This

approach can be used to evaluate the combined toxicity potential of congener mixtures by multiplying individual congener concentrations by their respective TEFs and summing the results. The World Health Organization (WHO) has derived TEFs specific to fish, birds, and mammals (van den Berg et al., 1998). Most PCB congeners have TEQs much less than 0.1. Although co-planars appear most toxic, other congeners may also be important contributors to PCB toxicity.

PCB Levels in the Spokane River

PCBs in Spokane River Fish

Ecology has analyzed PCBs in Spokane River fish collected in 1980, 1981, 1982, and 1983 (Hopkins et al., 1985), 1992 (Serdar et al., 1994), 1993 (Davis et al., 1995; Johnson et al., 1994), 1994 (EILS, 1995), 1996 (Johnson, 1997), and 1999 (Johnson, 2000a). The 1999 survey was a cooperative effort between the U.S. Geological Survey (USGS) and Ecology.

The most recent surveys of 1996 and 1999 focused on the upper portion of the river above Nine-Mile Dam (see Figure 2). Fish samples have not been collected downstream in Long Lake or in the Spokane River Arm of Lake Roosevelt since 1993-94. Most of the effort has been devoted to analyzing edible tissue to address human health concerns. Whole fish are more applicable to an ecological assessment, but these data are limited with respect to the number of species that have been analyzed, especially in the lower river. No data have been collected on PCB levels in forage fish or, except for crayfish, in macroinvertebrates. There are no PCB data for fish (or water or sediment) between Long Lake Dam and Little Falls Dam (river miles 33.9 – 29.3).

As already noted, most of the PCB data on the Spokane are reported as Aroclor-equivalents. The PCB mixtures in fish samples most closely resemble -1248, -1254, and -1260. Although -1248 and -1254 are the predominant mixtures identified in mainstem fish, -1260 predominated in fish collected from the Little Spokane River in 1994 and 1996, suggesting a possible different source of contamination in this tributary. PCB levels in Little Spokane fish were comparable to those found in the same species analyzed in Long Lake, to which it is tributary. All the Little Spokane samples have been taken near the mouth so may not be representative of the drainage as a whole.

Following EPA guidance (EPA, 1995) the present report sums Aroclor-equivalents to give total PCBs. Tables 1 (whole fish) and 2 (fillets) summarize the available fish tissue data.

Most fish samples have been composites, typically of five individual fish. The 1999 fillet data, however, were for individual fish (five per species per site). The 1999 fillet data shown in Table 2 were averaged for each species, amounting to the mathematical equivalent of a five fish composite. Information on the length, weight, sex, and age of the fish analyzed can be found in the references cited (sex and age recorded for 1999 only).

In general, PCB concentrations are moderate to low in fish collected from the Spokane River near the Idaho state line (river mile 96.5) and increase substantially downstream. The highest concentrations occur between Upriver Dam and approximately Trentwood (river mile 80.2 – 86.5). Concentrations begin to decrease below the dam and, by the Spokane Arm, are again moderate to low. Not that these data were all collected during the summer months and cannot address fish migration patterns during other times of the year.

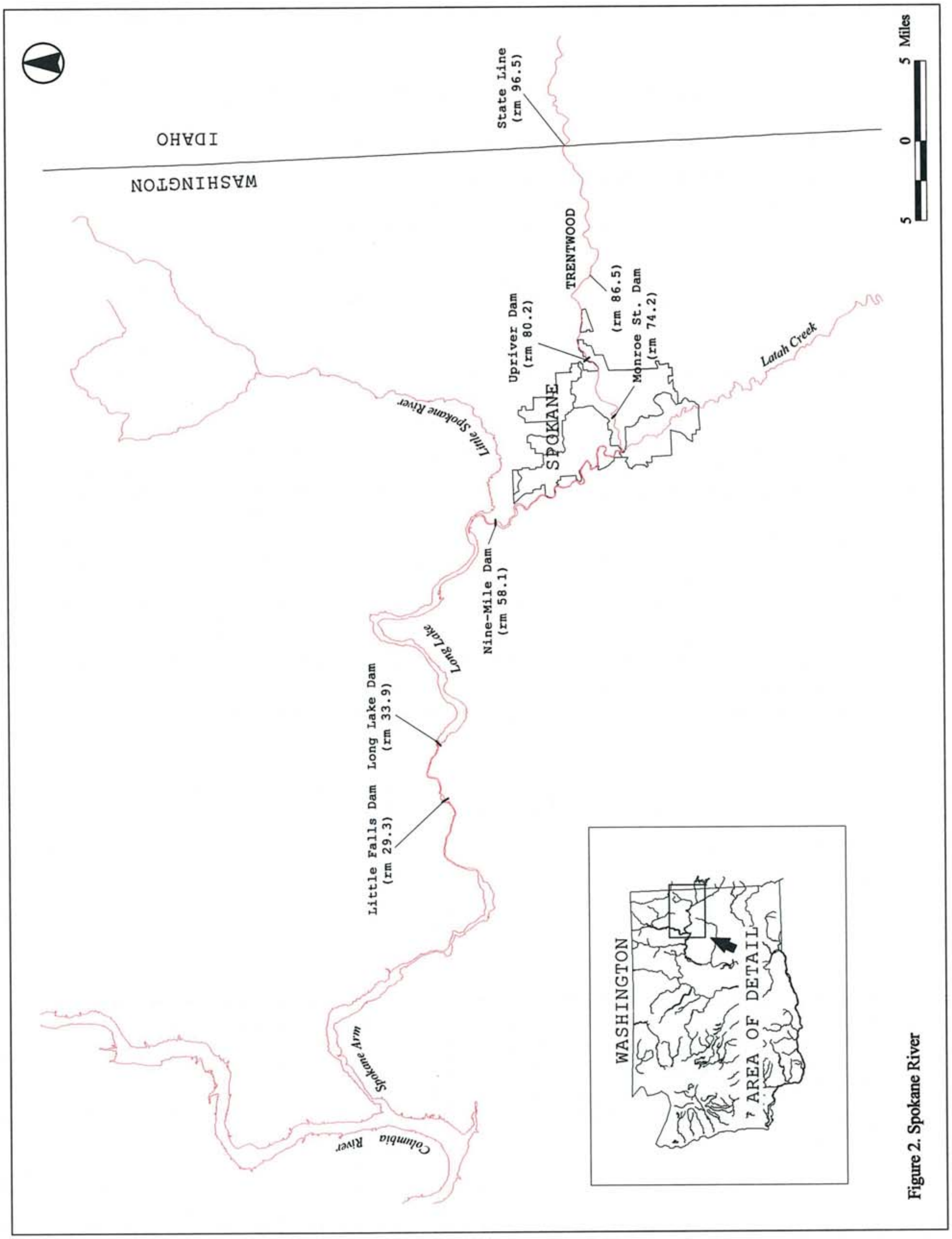

Figure 2. Spokane River

Table 1. Historical Record on Total PCBs in Spokane River **Whole** Fish Samples (ug/Kg, wet weight) [single composite samples]

Location	Date	Species	Total PCBs		% Lipid	Reference
Near Idaho Border	8/9/93	Largescale sucker	96		7.2	1
	8/20/94	Largescale sucker	152		5.5	2
	7/27/99	Largescale sucker	120		6.1	3
	7/27/99	Rainbow trout	77		8.3	3
Above Upriver Dam	9/93	Largescale sucker	1230		4.7	4
	7/27/93	Largescale sucker	2775		4.3	1
	8/6/94	Largescale sucker	531		3.6	2
	8/14/96	Largescale sucker	520		3.5	5
	7/28/99	Largescale sucker	283		4.5	3
	7/28/99	Rainbow trout	755		7.7	3
	10/14/99	Crayfish	15	U	0.2	3
Above Monroe St. Dam	8/8/94	Largescale sucker	201		1.2	2
	8/14/96	Largescale sucker	116		0.8	5
	7/29/99	Largescale sucker	444		2.5	3
	7/29/99	Rainbow trout	362		4.3	3
	7/29/99	Mountain whitefish	397		17	3
	10/14/99	Crayfish	15	U	0.2	3
Above Nine-Mile Dam	9/20/80	Largescale sucker	230		0.4	6
	8/4/81	Largescale sucker	160		5.2	6
	8/10/93	Largescale sucker	1210		5.6	1
	8/13/96	Largescale sucker	345		2.1	5
	7/30/99	Largescale sucker	680		2.2	3
	7/30/99	Rainbow trout	222		2.1	3
	8/31/83	Mountain whitefish	273		9.3	6
	7/30/99	Mountain whitefish	930		15	3
	10/14/99	Crayfish	13		0.2	3
Little Spokane River	8/3/94	Largescale sucker	440		4.3	2
	8/13/96	Largescale sucker	366		1.3	5
Long Lake	7/26/92	Largescale sucker	724		na	7
	7/27/93	Largescale sucker	410		2.3	1
	8/2/94	Largescale sucker	820		3.4	2
Spokane Arm	7/26/93	Largescale sucker	640		5.1	1

U = not detected at or above reported value
na = not analyzed
References:
1 = Johnson et al. (1994)
2 = EILS (1995)
3 = Johnson (2000a)
4 = Davis et al. (1995)
5 = Johnson (1997)
6 = Hopkins et al. (1985)
7 = Serdar et al. (1994)

Table 2. Historical Record on Total PCBs in Spokane River Fish **Fillet** Samples (ug/Kg, wet weight) [single composite samples, except average value shown for multiple individual fish analyzed in 1999]

Location	Date	Species	Total PCBs	% Lipid	Reference
Near Idaho Border	7/27/99	Largescale sucker	98	1.7	1
	7/27/99	Rainbow trout	106	4.0	1
Above Upriver Dam	9/93	Rainbow trout	720	2.7	2
	7/27/93	Rainbow trout	1084	1.9	3
	7/27/93	Rainbow trout	950	1.7	3
	8/6/94	Rainbow trout	385	2.9	4
	8/6/94	Rainbow trout	740	2.5	4
	8/6/94	Rainbow trout	471	2.8	4
	8/6/94	Rainbow trout	280	3.7	4
	8/14/96	Rainbow trout	1841	2.2	5
	8/14/96	Rainbow trout	313	2.4	5
	8/14/96	Rainbow trout	215	2.2	5
	7/28/99	Rainbow trout	880	3.2	1
	7/28/99	Largescale sucker	148	1.9	1
	8/6/94	Crayfish*	8 U	0.1	4
	8/6/94	Crayfish	7 U	0.2	4
	8/6/94	Crayfish	7	0.1	4
Above Monroe St. Dam	8/8/94	Rainbow trout	184	1.2	4
	8/8/94	Rainbow trout	111	1.1	4
	8/8/94	Rainbow trout	161	1.2	4
	8/8/94	Mountain whitefish	530	5.6	4
	8/8/94	Mountain whitefish	449	5.5	4
	8/8/94	Mountain whitefish	725	4.6	4
	8/14/96	Rainbow trout	73	1.5	5
	8/14/96	Rainbow trout	78	1.1	5
	8/14/96	Mountain whitefish	398	4.2	5
	8/14/96	Mountain whitefish	364	3.9	5
	7/29/99	Largescale sucker	189	0.8	1
	7/29/99	Rainbow trout	226	1.8	1
	7/29/99	Mountain whitefish	339	8.2	1
	8/8/94	Crayfish	7 U	0.2	4
	8/8/94	Crayfish	7 U	0.3	4
	8/8/94	Crayfish	7 U	0.2	4

Table 2. Fillet Data (continued)

Location	Date	Species	Total PCBs	% Lipid	Reference
Above Nine-Mile Dam	7/30/99	Largescale sucker	147	2.6	1
	7/30/99	Rainbow trout	142	0.6	1
	8/31/83	Mountain whitefish	226	8.6	6
	7/30/99	Mountain whitefish	642	3.9	1
	8/10/93	Rainbow trout	474	2.7	3
	8/10/93	Rainbow trout	505	2.9	3
	8/10/93	Mountain whitefish	522	2.7	3
	8/5/94	Rainbow trout	320	5.4	4
	8/5/94	Rainbow trout	205	3.0	4
	8/5/94	Rainbow trout	589	5.2	4
	8/5/94	Mountain whitefish	120	6.9	4
	8/5/94	Mountain whitefish	111	8.4	4
	8/5/94	Mountain whitefish	185	6.6	4
	8/13/96	Rainbow trout	63	1.5	5
	8/13/96	Rainbow trout	128	1.7	5
	8/13/96	Rainbow trout	38.4	1.5	5
	8/13/96	Mountain whitefish	616	4.4	5
	8/13/96	Mountain whitefish	430	5.5	5
	8/13/96	Mountain whitefish	343	5.1	5
Little Spokane River	8/3/94	Mountain whitefish	145	2.5	4
	8/3/94	Mountain whitefish	235	2.2	4
	8/3/94	Mountain whitefish	285	3.2	4
	8/3/94	Cutthroat trout	188	3.5	4
	8/13/96	Mountain whitefish	164	4.2	5
	8/13/96	Mountain whitefish	130	3.0	5
	8/13/96	Mountain whitefish	53	2.0	5

Table 2. Fillet Data (continued)

Location	Date	Species	Total PCBs	% Lipid	Reference
Long Lake	26/8/92	Yellow perch	75 U	0.2	7
	26/8/92	Largemouth bass	75 U	2.1	7
	7/27/93	Mountain whitefish	780	3.5	3
	7/27/93	Largemouth bass	97	0.6	3
	7/7/93	Yellow perch	9.4	0.2	3
	8/2/94	Mountain whitefish	160	3.6	4
	8/2/94	Mountain whitefish	118	3.4	4
	8/2/94	Mountain whitefish	71	1.9	4
	8/2/94	Largemouth bass	94	1.0	4
	8/2/94	Largemouth bass	104	1.1	4
	8/2/94	Yellow perch	9	0.2	4
	8/2/94	Yellow perch	10	0.2	4
	8/2/94	Yellow perch	6	0.2	4
	8/2/94	Brown trout	193	4.0	4
	8/2/94	White crappie	98	2.5	4
	8/2/94	Squawfish	300	1.5	4
	8/2/94	Squawfish	206	1.6	4
	8/2/94	Squawfish	200	1.2	4
	7/7/93	Crayfish	17 U	0.4	3
	8/8/94	Crayfish	9 U	na	4
Spokane Arm	7/26/93	Smallmouth bass	28	1.2	3
	7/26/93	Kokanee	92	4.4	3
	7/26/93	Walleye	15	0.4	3
	8/2/94	Walleye	31	0.9	4
	8/2/94	Walleye	58	0.8	4
	8/2/94	Walleye	50	0.9	4

*tail muscle
U = not detected at or above reported value
References:
1 = Johnson (2000a)
2 = Davis et al. (1995)
3 = Johnson et al. (1994)
4 = EILS (1995)
5 = Johnson (1997)
6 = Hopkins et al. (1985)
7 = Serdar et al. (1994)

Figures 3 (whole fish) and 4 (fillets) illustrate this pattern, using mixed species data from the 1993 and 1999 surveys. The upper part of each figure plots total PCBs on a wet weight basis. In the lower part, the data are normalized to percent lipid by dividing the wet weight concentration by decimal fraction representing the percent lipid of the sample in question. Because PCBs are highly soluble in lipid and are sequestered by fish in lipid-rich tissues, much of the between-species variability in PCB concentrations can be due to lipid content.

The trend toward decreasing PCB concentrations downstream of Upriver Dam, seen in the 1993 data, is not as evident in 1999, in part due to no sampling having been done in Long Lake or the Spokane Arm. The results for 1999 suggest roughly comparable PCB levels between samples collected above Upriver Dam, above Monroe Street Dam, and above Nine-Mile Dam.

Statistical tests using the individual fillet data from 1999 showed no significant differences between largescale suckers and mountain whitefish collected above Upriver Dam, above Monroe Street Dam, and above Nine-Mile Dam (ANOVA). There was a significant difference ($p<0.05$) between rainbow trout at Upriver vs. Nine-Mile, but the Nine-Mile samples included planted fish.

Differences in the age and sex of the fish analyzed, the ability of fish to move up- and downstream, and other factors can obscure between-site differences within the river.
USGS obtained recent data on whole largescale suckers composites that are more consistent with the downstream trend seen in Ecology's 1993 samples. Total PCB concentrations in the USGS samples were 270 ug/Kg at Post Falls, Idaho, 500 ug/Kg at Otis Orchards, 310 ug/Kg at Trentwood, and 140 ug/Kg at Seven-Mile (http://idaho.usgs.gov/projects/spokane/index.html). These samples were collected in 1999 and 1998 (Seven-Mile). No sampling was done in Long Lake or in the Spokane Arm.

As previously noted, the only invertebrate analyzed from the Spokane River has been crayfish. Concentrations have been low to undetectable (Tables 1 and 2). The maximum concentration found was 13 ug/Kg total PCBs in a whole body sample.

Only limited analyses have been done for individual PCB congeners in Spokane River fish. Six samples from the 1993 collection were analyzed (Johnson, 1994), but these had some of the higher total PCB concentrations recorded for the Spokane, so the results are probably not representative of current levels. A more recent analysis was conducted on a subset of the 1999 samples (Table 3; Johnson, 2000a). A shortcoming of these data is that the detection limits for the most toxic congeners – PCB-77, -81, -126, and -169 – were not sufficiently low for optimum quantitation.

The question of whether PCB concentrations in Spokane River fish have been increasing or decreasing over time cannot be answered confidently with the data presently available. Sample size has been generally small, sometimes no more than a single sample per species per site. Prior to 1999 all samples were composites and, as such, provide no measure of the variability within the population. A simple comparison between composites may be misleading in that, prior to 1999, compositing was done without regard to fish size, potentially resulting in a biased estimate of the mean.

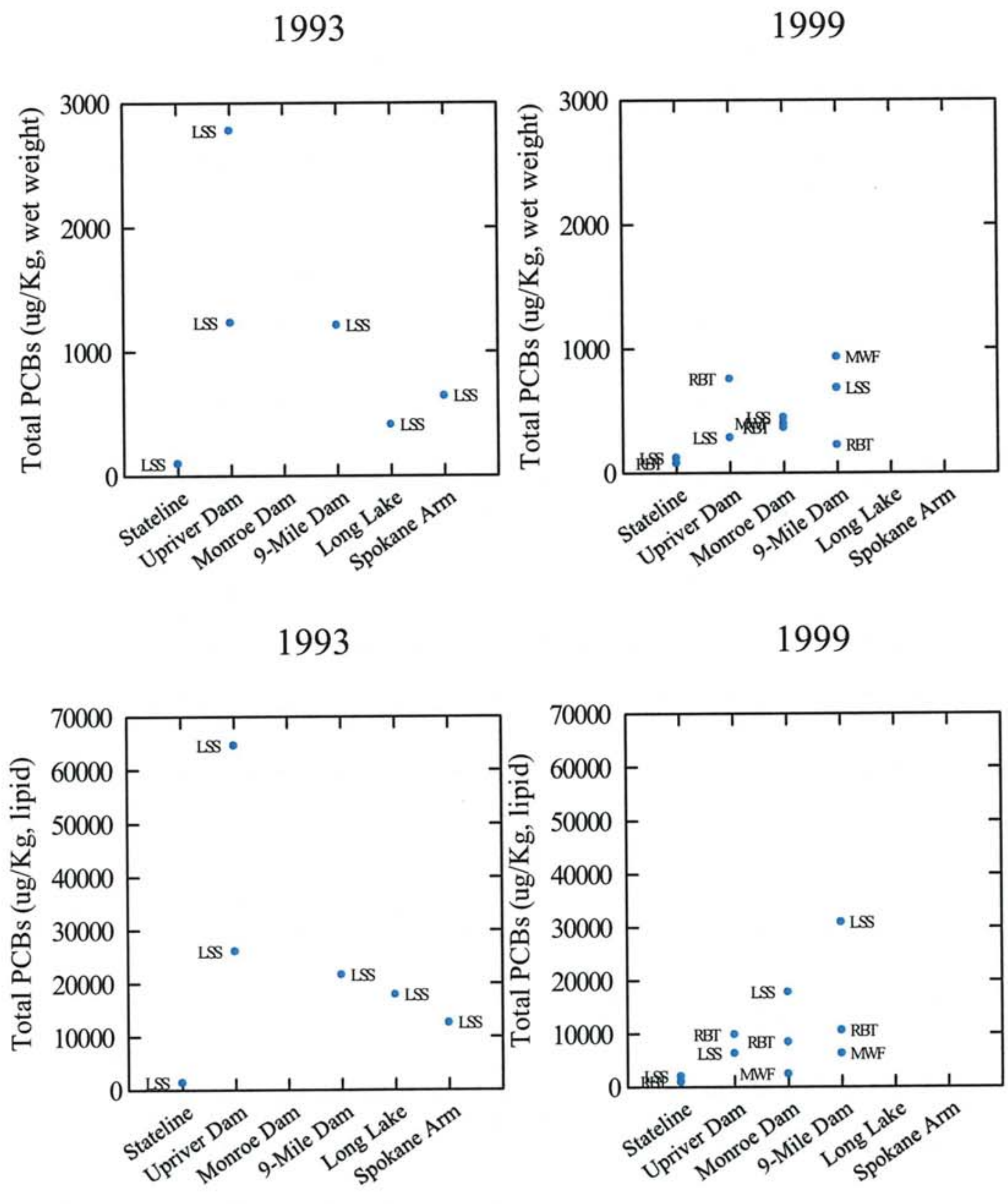

Figure 3. Downstream Trends in Total PCB Concentrations in Spokane River Whole Fish Samples Collected in 1993 and 1999 (composite samples, wet and lipid weight basis) [LSS = largescale sucker, RBT = rainbow trout, MWF = mountain whitefish]

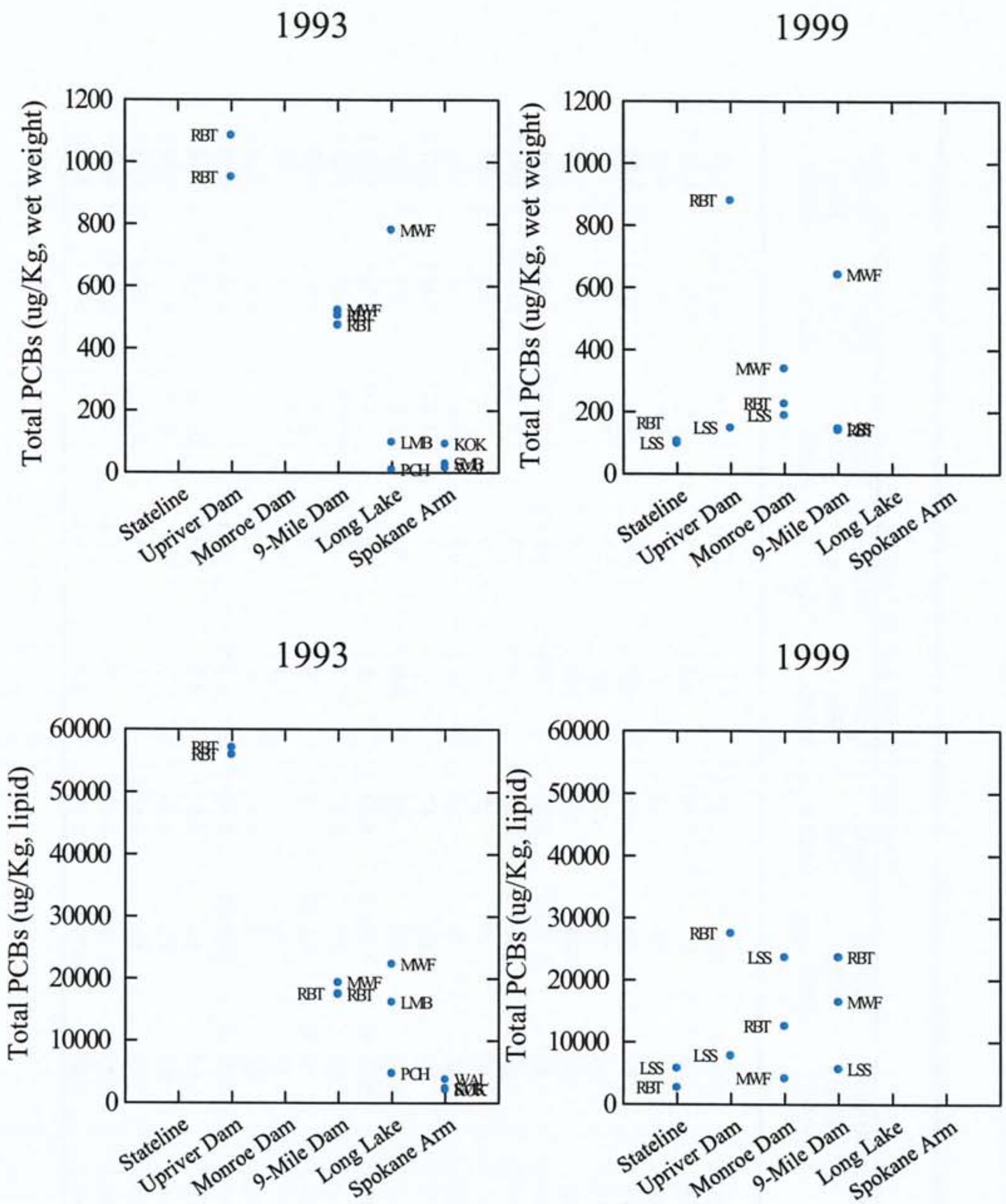

Figure 4. Downstream Trends in Total PCB Concentrations in Spokane River Fish Fillet Samples Collected in 1993 and 1999 (composite samples, wet and lipid weight basis) [LSS = largescale sucker, RBT = rainbow trout, MWF = mountain whitefish, LMB = largemouth bass, PCH = yellow perch, WAL = walleye, KOK = kokanee]

Table 3. Concentrations of PCB Congeners in 1999 Spokane River Fish Samples (ug/Kg, wet weight basis) [Johnson, 2000a]

Location:	Plante Ferry Site Park (r.m. 85.0 vicinity)								
Species:	Rainbow	Rainbow	Rainbow	Rainbow	Rainbow	Sucker	Sucker	Sucker	Sucker
Tissue:	Whole	Fillet	Fillet	Fillet	Fillet	Whole	Fillet	Fillet	Fillet
Sample Number:	485012	485013	485013-dup	485014	485015	485018	485019	485021	485022
PCB-8	0.91 U	0.89 U	0.89 U	0.89 U	1.7 U	1.6 U	1.5 U	0.91 U	0.91 U
PCB-18	0.95	3.0	2.7	0.29 J	1.7 U	0.95 J	1.9	0.26 J	0.91 U
PCB-28	8.0	37	33	1.0	17	5.7	6.5	1.1	0.47 J
PCB-44	15	27	25	1.1	29	7.5	8.0	1.3	0.87
PCB-52	32	80	73	2.0	81	7.7	7.1	1.3	1.3
PCB-66	59	130	120	2.6	170	17	13	2.7	3.0
PCB-77	0.91 U	0.89 UJ	0.89 UJ	0.89 U	13 UJ	1.6 UJ	1.5 UJ	0.91 U	0.91 U
PCB-81	0.91 U	0.89 UJ	0.89 UJ	0.89 UJ	6.6 U	2.3	1.5 U	0.91 U	0.91 U
PCB-101	27	48	44	1.5	74	10	7.1	2.0	2.3
PCB-105	27	46	41	1.3	64	6.9	4.3	1.4	1.6
PCB-114	3.3	5.3	4.6	0.47 J	13	2.5	1.5 U	0.44 J	0.47 J
PCB-118	43	70	62	2.0	100	13	7.5	2.7	2.9
PCB-126	0.91 U	0.78 NJ	0.79 NJ	0.89 U	6.6 U	1.6 U	1.5 U	0.91 U	0.91 U
PCB-128	3.0	4.4	3.9	0.25 J	7.4	1.4 J	0.71 J	0.23 J	0.28 J
PCB-138	3.3 J	4.6 NJ	4.3 NJ	1.2	30	5.9	2.8	0.26 J	0.29 J
PCB-153	13	17	15	1.5	25	6.2	2.7	1.1	1.2
PCB-156	2.2	3.6	2.9	0.36 J	12	1.6 U	1.5	0.36 J	0.34 J
PCB-169	0.91 U	0.89 UJ	0.89 UJ	0.89 UJ	6.6 U	1.6 U	1.5	0.91 U	0.91 U
PCB-170	3.3	4.4	4.1	0.39 J	4.9	1.4 J	0.65 J	3.2 J	0.30 J
PCB-180	6.6	8.9	8.2	0.86	13	3.0	1.3 J	0.62 J	0.51 J
PCB-187	3.6	4.6	4.3	0.61 J	3.3	1.6 J	0.83 J	3.0 J	0.35 J
PCB-195	0.66 J	0.85	0.79 J	0.89 U	1.7 U	1.6 U	1.5 U	0.91 U	0.91 U
PCB-206	0.62 J	0.89	0.79 J	0.89 U	1.7 U	1.6 U	1.5 U	0.91 U	0.15 J

Table 3. PCB Congeners (continued)

Location:	Greene Street (r.m. 77.0 vicinity)			
Species:	Whitefish	Whitefish	Whitefish	Whitefish
Tissue:	Fillet	Fillet	Fillet	Fillet
Sample Number:	485031	485032	485032 -dup	485033
PCB congener 8	0.90 U	0.90 U	3.2 U	0.89 U
18	0.76 J	0.90 U	3.2 U	0.89 U
28	5.4	18	23	12
44	5.8	0.61 J	14 U	1.4
52	11	0.65 J	39 U	2.1
66	13	42	53	27
77	0.90 U	3.3 UJ	6.4 UJ	0.89 UJ
81	0.90 U	0.90 U	8.4	0.89 UJ
101	14	2.4 UJ	4.5	5.7 J
105	7.9	22	24	16
114	2.4	2.5	3.2 U	2.9
118	14	37	44	28
126	0.90 U	0.90 U	3.2 U	0.78 NJ
128	1.6	3.4	4.6	3.0
138	1.9 J	15	19	12
153	7.9	16	19	14
156	2.3	2.7	3.2 U	4.6
169	0.90 U	4.0 UJ	6.4	5.7 UJ
170	1.8	4.3	4.6	3.3
180	3.5	9.0	11	6.8
187	2.2	2.5	3.2 U	2.8
195	0.40 J	0.76 J	3.2 U	0.60 J
206	0.47 J	0.72 J	3.2 U	0.64 J

U = not detected at or above reported value
J = estimated value N = evidence that analyte is present

From a qualitative standpoint, the evidence for trends over time is inconsistent (e.g., largescale suckers vs. rainbow trout above Upriver Dam) as shown in Figures 5 and 6 which plot the data for those species and locations most frequently sampled. The PCB data collected in 1999 may provide a better baseline for tracking changes in the future.

Statewide Fish Tissue Data

To understand how the level of PCB contamination in Spokane River fish ranks with other lakes, rivers, and streams in Washington, the 1999 data were compared to statewide data collected by Ecology between 1992 and 1998 (Appendix A). Land-use in the vicinity of the waterbodies represented by this data set ranges from urban/industrial (e.g., Chehalis River) to agricultural (e.g., Yakima River) to undeveloped (e.g., Soleduck River). The samples were collected, prepared, and analyzed following the same protocols as for the Spokane River. All samples were composites, typically of five individual fish.

Figure 7 shows how the 1999 Spokane River data for whole fish and fillets (excluding crayfish and the Little Spokane River samples) compare to results from approximately 80 statewide samples. The individual 1999 fillet data are plotted here. Where PCBs were not detected in a statewide sample, half the reported detection limit was used. The data for five statewide samples with poor detection limits (555 ug/Kg) were not included in the figure.

As shown in Figure 7, the level of PCB contamination in Spokane River fish is much higher than in other parts of the state. Whereas 50% of Spokane whole fish and fillet samples exceed approximately 350 ug/Kg and 200 ug/Kg total PCBs, respectively, only a few samples from other waterbodies approach or exceed these levels.

Although many of the samples in the statewide data set are from the same species analyzed from the Spokane River, comparison may be improved by lipid normalizing the data. The results (Figure 8) still show the level of PCBs in the Spokane to be unusually high.

As far as could be determined, no studies have been conducted in the Pacific Northwest that report a local background for PCBs in fish. The lowest total PCB concentrations Ecology has measured in fish from waterbodies without any known or suspected sources of contamination are < 10 ug/Kg wet weight (Lake Whatcom, Ward Lake, Elwha River: Appendix A). Given the widespread historic use of PCBs and their atmospheric transport, it is likely that fish from even the most remote lakes in Washington would have a few parts per billion detectable in their tissues.

National Fish Tissue Data

National surveys that have analyzed PCBs in fish tissue include the above-mentioned EPA (1992) study, the U.S. Fish and Wildlife Service (USFWS) National Contaminant Biomonitoring Program (Schmitt et al., 1990), and the USGS National Water Quality Assessment Program.

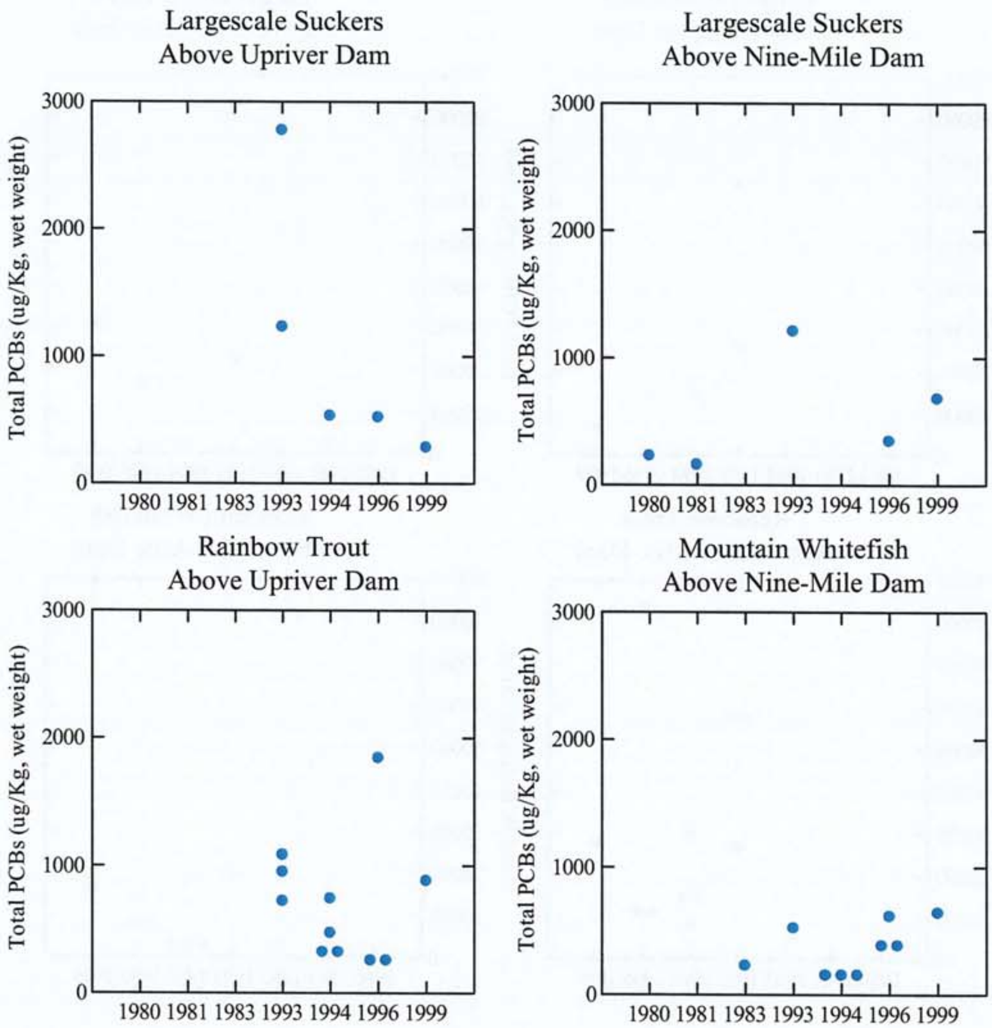

Figure 5. Historical Data on Total PCBs in Whole Largescale Suckers, and Rainbow Trout and Mountain Whitefish Fillets from Selected Locations in the Spokane River (composite samples, wet weight basis)

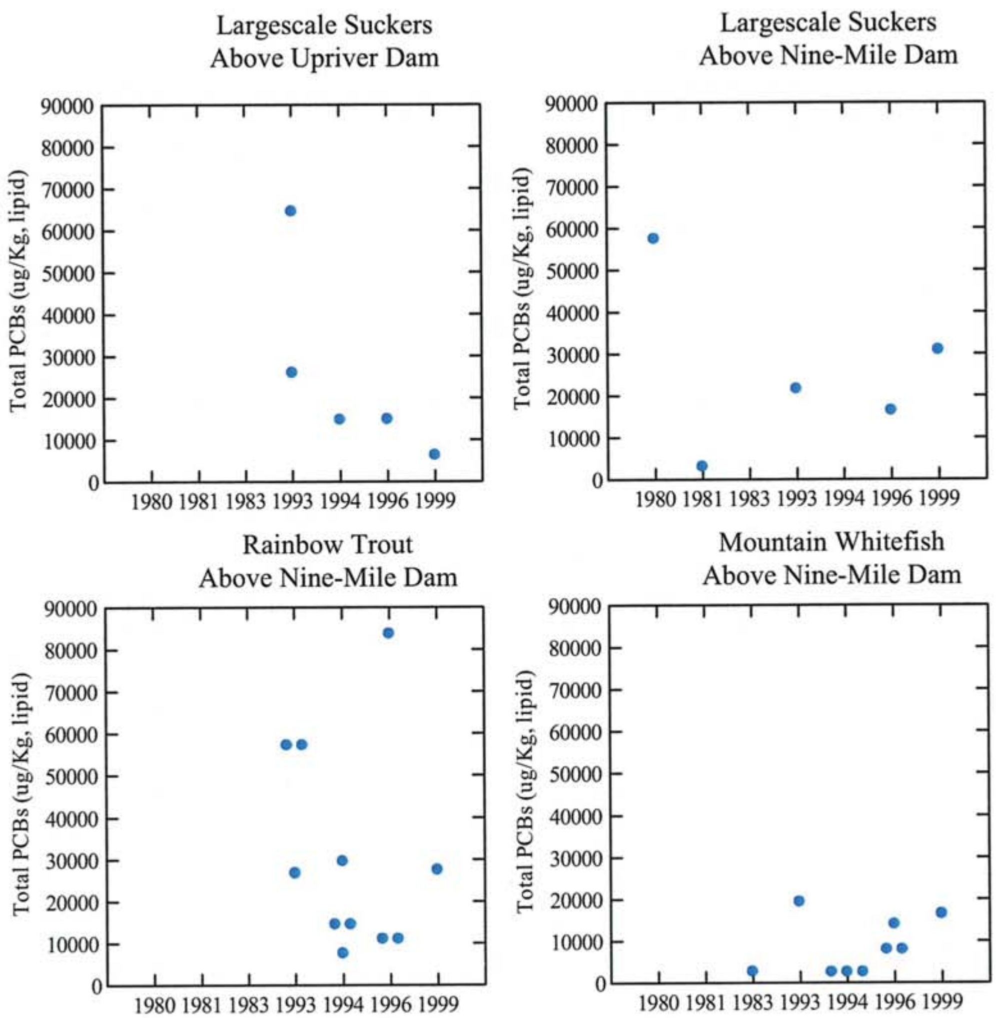

Figure 6. Historical Data on Total PCBs in Whole Largescale Suckers, and Rainbow Trout and Mountain Whitefish Fillets from Selected Locations in the Spokane River (composite samples, lipid weight basis)

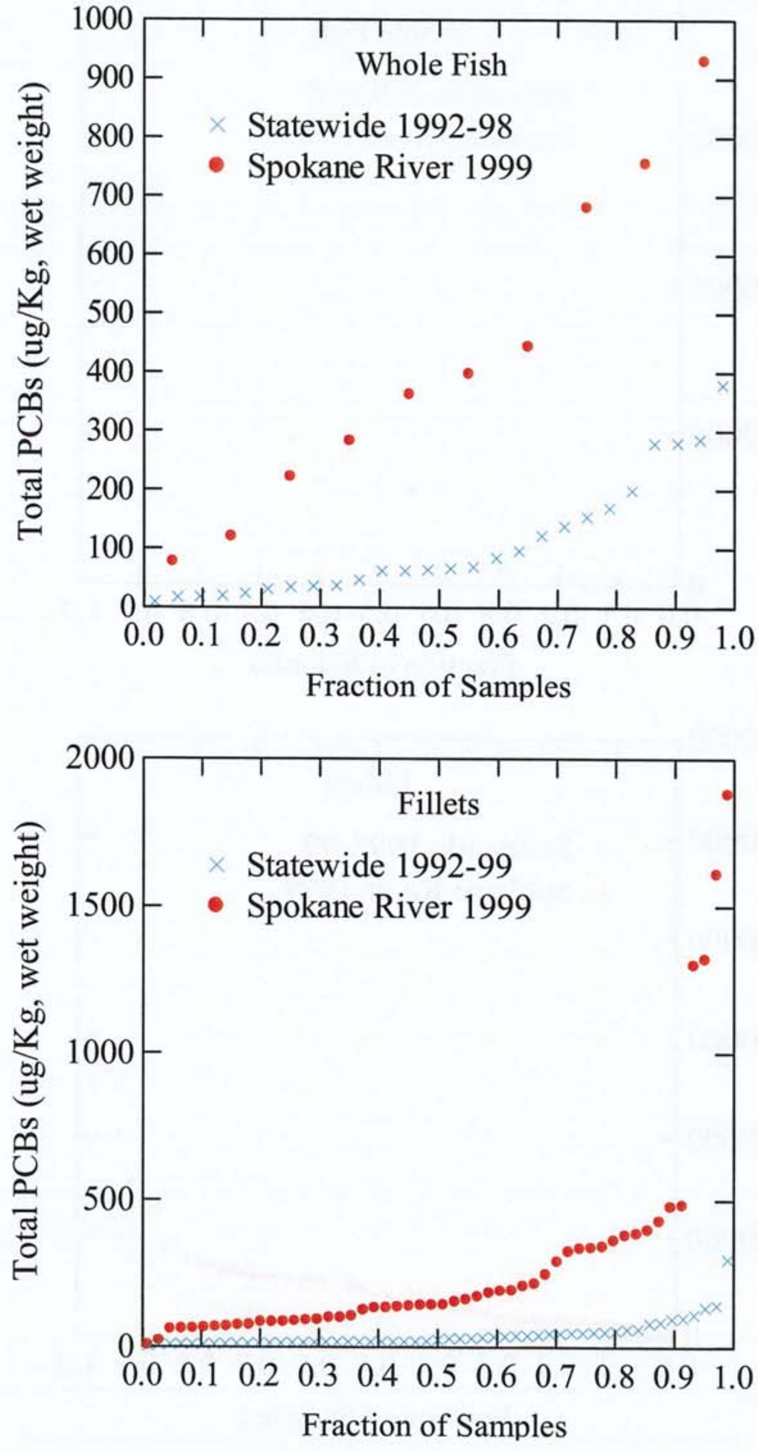

Figure 7. Ecology Data on Total PCBs in Washington State Freshwater Fishes: Spokane River Compared to Other Lakes, Rivers, and Streams (wet weight basis)

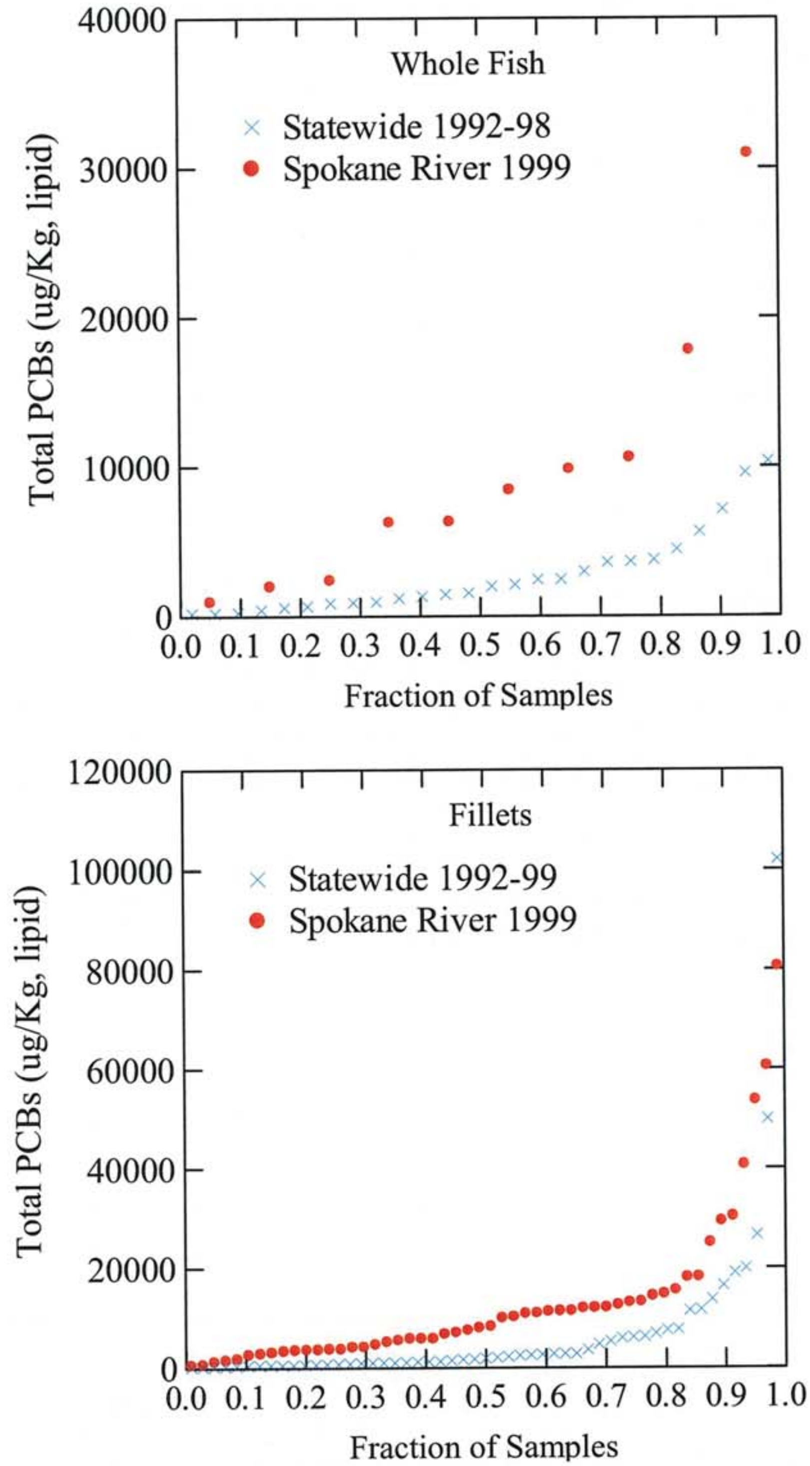

Figure 8. Ecology Data on Total PCBs in Washington State Freshwater Fishes: Spokane River Compared to Other Lakes, Rivers, and Streams (normalized to percent lipid)

Samples for these efforts were collected in 1984 (USFWS), 1986-87 (EPA), and 1992-94 (USGS, as summarized in Maret and Dutton, 1998). EPA is currently conducting the field work for a second national study on chemical contaminants in fish.

Table 4 summarizes results from these large-scale national studies and compares them to the 1999 Spokane River data. The national data are for whole fish or, in the case of EPA, a mix of whole fish and fillets. Also shown in 4 are summary statistics from the Washington statewide data previously discussed.

Table 4. Summary of National, Statewide, and Spokane River Data on PCB Levels in Freshwater Fish (total PCBs in ug/Kg, wet weight)

Study	Investigator	Year	Samples/ Sites	Median	85th Percentile	Max.	Reference
			National Data				
National Contaminant Biomonitoring Program[a]	USFWS	1984	112 / 321	390[c]	nr	6,700	Schmitt et al. (1990)
National Study on Chemical Residues in Fish[b]	EPA	1986-87	nr / 362	209	nr	23,800	EPA (1992)
National Water Quality Assessment Program[a]	USGS	1992-94	213 / --	<50	356	nr	Maret & Dutton (1998)
			Washington State Data				
Washington State Pesticide Monitoring Program and other studies[b]	Ecology	1992-98	33 / 78	36	115	379	see Appendix A
			Spokane River Data				
Whole fish	Ecology/	1999	10 / 4	380	729	930	Johnson (2000a)
Fillets	USGS		52 / 4	143	390	1880	

[a]whole fish data

[b]whole fish and fillet data

[c]geometric mean

nr = not reported

The median concentration of total PCBs in the 1999 whole fish samples from the Spokane River substantially exceeds the national medians reported by EPA and USGS. The USFWS median is comparable to the Spokane. The comparison with the EPA and USFWS data is somewhat misleading, in that the EPA study was weighted toward contaminated sites and the USFWS data represent conditions 15 years ago. The 85^{th} percentile for Spokane whole fish is twice the USGS 85^{th} percentile.

Although elevated and of human health and ecological significance, the PCB levels in Spokane River fish pale by comparison to some of the most contaminated sites in the nation. For example, in New York's Hudson River and in the Lower Fox River in Wisconsin, total PCB concentrations in fish samples have exceeded 10,000 ug/Kg (TAMS, 2000; ThermoRetec, 1999).

PCBs in Spokane River Sediment

PCBs have been analyzed in Spokane River sediment samples collected by Ecology in 1993, 1994, 1999, and 2000 (EILS, 1995; Johnson, 2000b; and Johnson, in prep.)[2]. Again, most of the data are for the upper river. All samples have been composites, but the depth increment has varied from the top 2-cm to the top 10-cm. Results are summarized as total PCBs in Table 5 and Figure 9. Average values were plotted for multiple samples from the same sites, and non-detects were plotted at half the detection limit.

Because the river bed between the Idaho border and the city of Spokane is mostly cobble and gravel, sediment samples in this reach have come from isolated pockets of fine material, often sampled by hand. Somewhat larger depositional areas have been located in the vicinity of Upriver Dam (river mile 80.2 – 80.6) but these are also patchy in their occurrence.

As with fish tissue, PCB concentrations are moderate-to-low in sediment collected in Idaho. Generally low concentrations continue down to river mile 81.5 below Argonne Road bridge. High concentrations of 1,273 – 4,500 ug/Kg total PCBs have been found in finer deposits behind Upriver Dam, at several sites along the right (north) bank of the river. The uneven nature of PCB distribution in this area is illustrated by PCB levels off the right vs. left bank (Table 5).

Some notable PCB concentrations, 190 – 300 ug/Kg, have also been reported at isolated locations between Upriver Dam and Monroe Street Dam. While PCB-1254 has been the predominant apparent mixture identified above the state line, -1248 appears predominant in sediments between the state line and Monroe Street Dam.

PCB levels in the sediments between Spokane and Nine-Mile Dam are essentially unknown. Much of this reach is free-flowing and non-depositional. Also, Latah Creek enters below Spokane and contributes substantial Palouse-derived sediment into the river system. Only one site has been sampled and this was probably influenced by the sediment load from Deep Creek;

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[2] USGS (http://idaho.usgs.gov/projects/spokane/index.html) and Kaiser Aluminum & Chemical Corp (Hart Crowser, 1995) have also analyzed PCBs in Spokane River sediment, but at detection limits generally too high for quantifying the concentrations present.

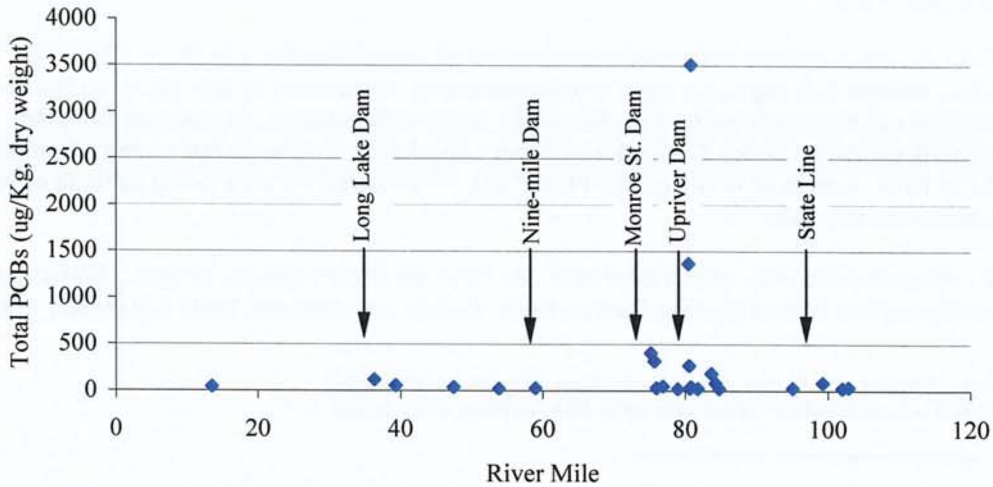
Table 5. Total PCBs in Spokane River Sediment Samples (ug/Kg, dry weight)

Location	River Mile	Date	Total PCBs	% TOC	% Fines[a]	Depth (cm)	Ref.
Idaho							
Above Post Falls Dam	102.6	Jul-93	19	2.7	26	2	1
Above Post Falls STP	101.7	Aug-94	16 U	2.6	16	2	1
Pleasant View Road	99.0	May-94	210	na	na	2	1
" " "	99.0	Aug-94	15 U	2.6	7	2	1
(duplicate analysis)	99.0	Aug-94	16 U	na	na	2	1
State Line to Upriver Dam							
State Line	94.8	Aug-94	17	5.2	26	2	1
(duplicate analysis)	94.8	Aug-94	17 U	na	na	2	1
Myrtle Point	84.5	Aug-94	5.3	0.4	1	2	1
1/2 Mile below Myrtle Pt.	84	Aug-94	67	1.1	1	2	1
Beach below Myrtle Pt.	83.4	Aug-94	170	2.2	6	2	1
" " " "	83.4	Oct-99	67	1.8	2	10	2
Boulder Beach	81.5	Aug-94	11	1.1	5	2	1
" "	81.5	May-94	10 U	na	na	2	1
Above Upriver Dam (RB[b])	80.6	Jul-93	3000 J	11	34	2	1
" " "	80.6	Aug-94	2453 J	11	22	2	1
(duplicate analysis)	80.6	Aug-94	2700 J	na	na	2	1
Above Upriver Dam (RB)	80.6	Aug-94	4500	13	33	5	1
Above Upriver Dam (RB)	80.6	Oct-00	1307	2.5	3	10	3
Above Upriver Dam (LB[c])	80.6	Aug-94	20 J	2.2	10	2	1
(duplicate analysis)	80.6	Aug-94	26 J	na	na	2	1
Above Upriver Dam (RB)	80.4	Oct-99	17 U	14	13	10	2
" " "	80.3	Oct-99	254	3.6	6	10	2
At Upriver Dam	80.2	Oct-99	1273	8.4	17	10	3
" " "	80.2	Oct-00	1431	6.6	21	10	3
(duplicate analysis)	80.2	Oct-00	1427	6.8	na	10	3
Upriver Dam to Monroe Street Dam							
Below WWP Yard	78.7	Aug-94	3.6 J	2.2	2	2	1
Mission Street Bridge	76.6	Aug-94	31	0.4	2	2	1
Old Bridge	75.7	Aug-94	13	1.0	na	2	1
Near Post Office	75.4	Aug-94	300	0.8	3	2	1
Above Division Street	74.9	Aug-94	390	2.5	6	2	1

Table 5. PCBs in Sediment (continued)

Location	River Mile	Date	Total PCBs	% TOC	% Fines[a]	Depth (cm)	Ref.
Latah Creek	1.1	Oct-00	5 U	0.3	2	10	3
Above Nine-Mile Dam							
Downstream of Deep Cr.	58.7	Jul-93	9.1 J	1.8	6	2	1
Little Spokane River	1.4	Oct-99	5 U	0.2	5	10	3
Long Lake							
Upper Long Lake	53.6	Oct-99	2	0.5	19	10	3
Middle Long Lake	47.2	Oct-99	17	2.3	96	10	3
Off DNR Campground	39.0	Jul-93	53 J	3.9	98	2	1
(duplicate analysis)	39.0	Jul-93	33 J	na	na	2	1
Off DNR Campground	39.0	Aug-94	21	0.8	19	5	1
Lower Long Lake	36.0	Oct-99	99	2.6	97	10	3
Spokane Arm							
Porcupine Bay	13.2	Jul-93	14 J	1.8	67	2	1
" "	13.2	Aug-94	35	1.8	94	5	1

[a]silt+clay fractions (<0.004 - 0.063 mm)
[b]RB = right bank (facing downstream)
[c]LB = left bank (facing downstream)
U = not detected at or above reported value
J = estimated value
na = not analyzed
References:
1 = EILS (1995)
2 = Johnson (2000b)
3 = Johnson (in prep.)



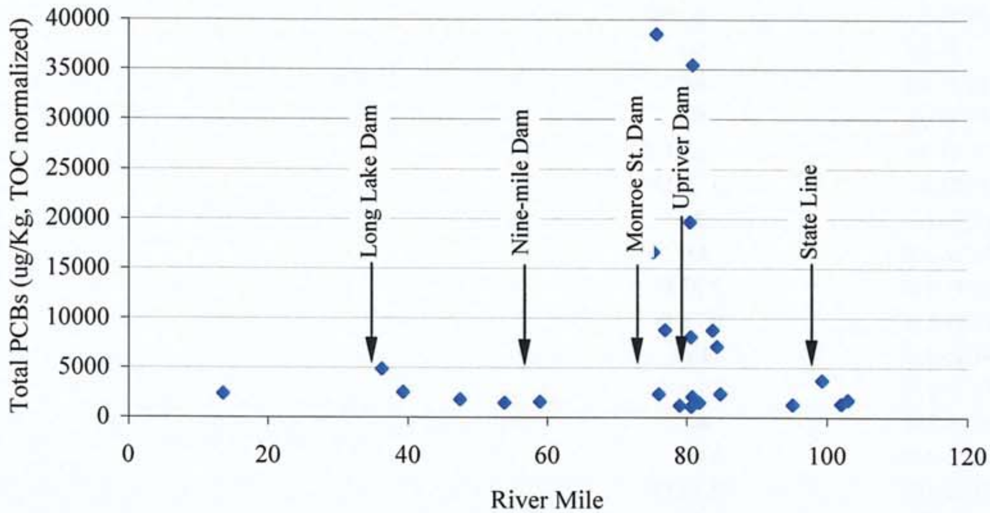


Figure 9. Total PCBs in Spokane River Sediment Samples

total PCBs were 9.1 ug/Kg. No PCBs were detected (<5 ug/Kg) in the single sample analyzed from Latah Creek.

Total PCB concentrations in the bottom sediments of Long Lake range from 2 – 99 ug/Kg. The limited available data suggest a trend toward increasing concentrations moving down the lake. PCBs have not been detected (< 5 ug/Kg) in the single sediment sample analyzed from the Little Spokane River, which discharges to upper Long Lake. Two sediment samples from the Spokane River Arm have been analyzed for PCBs. Concentrations were comparable to or lower than those in Long Lake.

PCB congeners have only been analyzed in one Spokane River sediment sample. That sample was collected just behind Upriver Dam in 1999. Results are shown in Table 6 (Johnson, 2000b).

Table 6. Results of a PCB Congener Analysis on a Sediment Sample Collected behind Upriver Dam in October 1999 (ug/Kg, dry weight)

PCB Congener	Concentration
PCB-8	14
PCB-18	67
PCB-28	80 NJ
PCB-44	63
PCB-52	69
PCB-66	63
PCB-77	35 UJ
PCB-81	0.73 U
PCB-101	20
PCB-105	9.0
PCB-114	0.73 U
PCB-126	0.73 U
PCB-128	1.6
PCB-138	6.4
PCB-153	4.7
PCB-156	0.86
PCB-169	0.73 U
PCB-170	0.96
PCB-180	2.1
PCB-187	1.2
PCB-195	0.73 U
PCB-206	0.73 U
PCB-209	0.73 U

U = not detected at or above reported value
UJ = not detected at or above reported estimated value
NJ = evidence the analyte is present, numerical results is an estimate

Kaiser Aluminum and Chemical Corporation, Trentwood Works, analyzed a sediment core collected behind Upriver Dam in 1994 (Hart Crowser, 1995). They found a sub-surface peak of approximately 14,700 ug/Kg total PCBs at a depth of 25 – 30 cm. Based on activity of the fallout radionuclide Cs-137, the PCB peak corresponded to the early 1960s. The PCB mixture resembled -1248.

PCBs in Spokane River Water

Measuring PCB concentrations in surface water is difficult due to their low solubility. The only water data available for the Spokane are for the upper river, focusing on the area of the Kaiser Trentwood outfall.

In 1994 Ecology analyzed suspended matter samples collected by continuous centrifuges operating during July 30 – August 5 at Barker Road (river mile 90.5) and Plante Ferry (river mile 84.7) (EILS, 1995). Results showed no PCBs detected in the upstream sample (<67 ug/Kg) and 220 ug/Kg PCB-1248 in the downstream sample (dry weight).

In the same study, estimates of soluble PCB concentrations were obtained by deploying semipermeable membrane devices (SPMDs) at the state line and at Plante Ferry during August 9 – September 14. SPMDs are passive samplers that take up PCBs by diffusion into a synthetic lipid (triolein). PCB concentrations in the ambient water are estimated from temperature-dependent PCB uptake rates determined in the laboratory.

Results of analyzing the SPMDs showed estimated PCB-1248 concentrations of 0.8 ng/L upstream and 1.0 – 1.9 ng/L downstream (parts per trillion). A study conducted at the same time by Kaiser reported no PCBs detectable above their outfall (<0.2 ng/L) and 1.3 – 1.8 ng/L PCB-1248 below the outfall (Hart Crowser, 1995).

In a more recent study by Kaiser (Anchor Environmental, 2000) SPMDs were deployed at five locations in the Spokane River between Harvard Road (river mile 93.0) and Riverside State Park (river mile 67.0). The sampling devices were left in the river from late July to early September 2000, the low-flow period. Thirty-five PCB congeners were analyzed.

Kaiser's results are summarized in Table 7. Kaiser calculated a total PCB concentration based on a correlation developed by the NOAA Status & Trends Program. Estimated total dissolved PCB concentrations in the Spokane River were reported to be <0.1 ng/L above the Kaiser outfall, 0.70 ng/L below the outfall, and 0.33 – 1.25 ng/L downstream of the outfall.

The highest PCB concentration and most congeners detected were recorded for the Riverside Park site. At the low levels being analyzed, the precision of these data appears reasonably good, as indicated by results on a duplicate sample from the Trent Road site (Table 7). However, more data would be needed to clearly establish whether there are significant differences in PCB concentrations between sites.

Table 7. Summary of Kaiser Data on PCB Concentrations in Spokane River Water; Based on SPMDs Deployed July - September 2000 (estimated dissolved concentrations in ng/L; only detected congeners shown)

PCB Congener	Below Harvard Rd. r.m. 93.0	Above Kaiser Intake r.m. 86.2	Trent Road Bridge r.m. 85.5	Trent Road (duplicate) r.m. 85.5	Above Greene St. r.m. 79.7	Riverside St. Park r.m. 67
PCB-8	U	U	0.04 J	0.03 J	U	U
PCB-105	U	U	0.08 J	0.04 J	U	0.08 J
PCB-118	U	U	0.11	0.07 J	0.07 J	0.14
PCB-128	U	U	U	U	U	0.18
PCB-138	U	U	0.03 J	0.03 J	0.03 J	0.07 J
PCB-153	0.05 J	U	0.09 J	0.05 J	0.06 J	0.16
Total detected congeners	0.05 J	0.1 U	0.35 J	0.22 J	0.16 J	0.63 J
Total PCBs*	0.09 J	0.1 U	0.70 J	0.44 J	0.33 J	1.25 J

Source: Anchor Environmental (2000)
U = analyte was not detected above the method reporting limit
J = analyte was detected in the sample and associated QA/QC samples at similar concentrations.
*estimated from NOAA Status & Trends Program correlation

Ecology attempted to quantify PCBs in whole water samples collected above and below the Kaiser outfall in August 2000 (Golding, 2001). As a result of method blank contamination, the data for PCB-1254 and -1260 were not useable. PCB-1248 was detected, but in only one of the 12 river water samples analyzed. That sample was collected just downstream of the Argonne Road bridge and had 1.1 ng/L. PCB-1248 was undetected in the other 11 samples at 0.9 – 1.0 ng/L. A congener-specific analysis was conducted, but also suffered from laboratory contamination problems.

Other Chemical Contaminants

Metals contamination of the Spokane River with zinc, cadmium, and lead from upstream sources in Idaho is well known. A number of the previously referenced reports contain data on metals concentrations in fish and sediment. Water data can be found in Pelletier (1994) and Hopkins & Johnson (1997). A TMDL for zinc, cadmium, and lead was proposed by Pelletier & Merrill (1998) and approved by EPA.

Kadlec (2000) did an ecological risk analysis for the elevated metals concentrations in the Spokane. He concluded that metals were suppressing productivity in phytoplankton and

macroinvertebrate communities. He further concluded that zinc and other metals have probably changed the abundance and distribution of fish populations but did not appear to be threatening their survival. Some level of adverse effects was considered likely to have occurred as far downstream as the Spokane Arm. Only minor metals-induced impacts were expected on wildlife.

The concentrations of bioaccumulative pesticides in Spokane River fish are low. Only trace concentrations of the DDT breakdown product DDE (18 – 39 ug/Kg) and trans-nonachlor (1 ug/Kg) were detected in suckers and rainbow trout collected above Upriver Dam in 1993 (Davis et al., 1995). DDT compounds were the only pesticides detected in Long Lake fish sampled in 1992 (Serdar et al., 1994). Yellow perch and largemouth bass fillets had <2 ug/Kg DDE. DDE, DDT, and DDD were detected in whole largescale suckers; the total DDT concentration was 107 ug/Kg. Statewide, the median total DDT concentration in freshwater fish is around 100 ug/Kg (Serdar et al., 1998).

Similar results for DDT compounds have been obtained by USGS (http://idaho.usgs.gov/projects/spokane/index.html). They analyzed organochlorine pesticides in upper Spokane River fish tissue and sediment samples collected in 1998-99. Only DDE and DDD were detected. Fish tissue concentrations of DDE were 11 – 20 ug/Kg. Both DDE and DDE were detectable in sediment at concentrations ranging from 1.2 – 4.5 ug/Kg

Pesticides have been analyzed in water samples collected from Latah Creek and Deadman Creek in 1996 (Davis, 1998). Only herbicides were detected and at trace levels (<0.03 ug/L; parts per billion).

There are isolated occurrences of elevated concentrations of semivolatile organic compounds in the sediments above Upriver Dam (Johnson, 2000b). Here, localized pockets of fine material exceed sediment quality guidelines for polyaromatic hydrocarbons, 4-methylphenol, retene, benzyl alcohol, and benzoic acid, in addition to zinc, cadmium, lead, and PCBs.

Polybrominated diphenyl ethers (PBDEs) were also analyzed in the 1999 Spokane River fish tissue samples (Johnson, 2000a). PBDEs have come into extensive use as flame retardant additives to paints, plastics, textiles, and electronics. Due to their persistence, lipid solubility, and structural similarity to dioxins and PCBs, PBDEs are emerging as a new class of environmental contaminants (Environment Canada, 1999; Renner, 2000). Toxicity information on these compounds, however, is currently too limited to assess the ecological significance of their detection in Spokane fish. PBDEs appear to be much less toxic than PCBs.

Ecology has analyzed PBDEs in 16 fish tissue samples from around Washington State (Johnson and Olson, 2001). Concentrations of total PBDEs ranged from approximately 2 ug/Kg in undeveloped watersheds to a maximum of 1,250 ug/Kg in one of the 1999 mountain whitefish samples from the Seven-Mile area of the Spokane River. The highest concentrations were found in urbanized watersheds (Spokane, Yakima, and Snake rivers) compared to undeveloped watersheds. The concentration of 1,250 ug/Kg measured in Spokane whitefish is comparable to the high levels seen in Lake Michigan steelhead and in carp from the Dan River in Virginia (M. Hornung, Univ. Wisconsin, personal communication; Renner, 2000).

The high lipid content (15%) in the above-mentioned whitefish sample no doubt contributed to the elevated PBDE concentration. The average total PBDE concentrations in the 1999 whole fish samples from the Spokane River were 178 ug/Kg in largescale suckers, 300 ug/Kg in rainbow trout, and 675 ug/Kg in mountain whitefish. Concentrations increase going from the state line to Seven-Mile, the most downstream location sampled. No PBDEs were detectable in crayfish (<1.5 ug/Kg).

PCB Ecological Hazard

Assessment Endpoints

From an ecological point of view, the concern with PCBs is the degree to which the sustainability (survival, growth, and reproduction) of aquatic and wildlife populations are affected. *Assessment endpoint* is the term used in ecological risk assessment to identify specific environmental values to be protected (EPA, 1998). They are expressed in terms of a receptor (e.g., species) and an attribute (e.g., reproduction). The criteria for selecting assessment endpoints are: 1) ecological relevance, 2) susceptibility to the stressor, and 3) whether they represent management goals (EPA, 1998). For purposes of the present assessment, five endpoints were evaluated:

- Sustainability of the water column invertebrate community, as a food source for fish and wildlife
- Sustainability of the benthic invertebrate community, as a food source for fish and wildlife
- Sustainability of local fish populations
- Sustainability of local fish-eating bird populations
- Sustainability of local fish-eating mammal populations

Benchmarks for PCBs

The potential ecological hazard of PCBs in the Spokane River was evaluated by comparing concentrations that have been measured in water, sediment, and tissue to toxicological benchmarks that could affect the sustainability of the river's invertebrate, fish, and wildlife populations. Numerous benchmarks are available, ranging from effects levels determined in individual laboratory studies to national numeric criteria based on large data sets. A literature search was conducted to locate benchmarks for total PCBs and PCB-TEQs appropriate for the Spokane River. Because of the limited congener data on the Spokane, benchmarks for individual PCB congeners were not evaluated (e.g., Stortelder et al., 1991). Benchmarks expressed in terms of specific Aroclor mixtures are available but were not used in view of the lack of resemblance between PCB mixtures in the environment and commercial Aroclors, and the availability of a more comprehensive set of benchmarks for total PCBs.

Where sufficient data were available, hazard quotients (HQ) were calculated for six separate reaches of the river, divided as follows:

- State Line to Trentwood (river mile 96.5 – 86.5)
- Trentwood to Upriver Dam (river mile 86.5 – 80.2)
- Upriver Dam to Monroe Street Dam (river mile 80.2 – 74.2)
- Monroe Street Dam to Nine-Mile Dam (river mile 74.2 – 58.1)
- Long Lake (river mile 58.1 – 33.9)
- Spokane Arm (river mile 29.3 – 0)

The HQ was defined as the PCB or PCB-TEQ concentration in the sampled media divided by the benchmark PCB or TEQ value. A quotient greater than 1.0 indicates the PCB concentration may be hazardous to aquatic life or wildlife. A weight-of-evidence approach was then used to characterize the hazard for each of the assessment endpoints by river reach. The benchmarks selected for this assessment are discussed below.

Water

The benchmarks located for total PCBs in the water column are summarized in Table 8. Values range from the Washington State acute standard of 2.0 ug/L (the EPA acute criterion) down to 74 pg/L (0.000074 ug/L), the EPA Great Lakes water quality criteria for protecting fish-eating mammals (EPA, 1995b).

Table 8. Toxicological Benchmarks for Assessing Hazards of Total PCBs to Aquatic Life: WATER [**Bold** values used in present assessment]

No.	Receptor	Concentration	Units	Type	Effect	Reference
1	algae	> 0.5 - 1	ug/L	LOEL	mortality, growth, reproduction	Nimmi, 1996
2	zooplankton	> **0.5**	ug/L	LOEL	mortality, growth, reproduction	Nimmi, 1996
3	aquatic life	**2.0**	ug/L	EPA acute criterion	acute toxicity	EPA, 1980
4	"	0.014	ug/L	EPA chronic criterion	mink reproduction	
5	aquatic life	**0.001**	ug/L	Canadian guideline	acute/chronic toxicity	CCREM, 1987
6	wildlife	0.0001	ug/L	British Columbia guideline	chronic toxicity and reproduction	BCMOELP, 1992
7	fish-eating birds	**230**	pg/L	Great Lakes criterion	reproduction	EPA, 1995b
8	fish-eating mammals	**74**	pg/L	Great Lakes criterion	reproduction	

Nimmi (1996) assessed the toxicological implications of PCB residues in aquatic organisms. He concluded that the lowest observable effects levels (LOELs) were >0.5 – 1 ug/L for algae and >0.5 ug/L for zooplankton, slightly lower than EPA's acute criterion.

The EPA chronic aquatic life criterion of 0.014 ug/L is intended to prevent harmful accumulations of PCBs in mink prey items. EPA considers this value to be too high because it was based on a low bioaccumulation factor determined in the laboratory (EPA, 1980). Canada's lower aquatic life guideline of 0.001 ug/L, although intended to protect marketability of edible fish, includes consideration of toxicity to fish, invertebrates, and algae (CCREM, 1987).

British Columbia has a criterion of 0.0001 ug/L total PCBs in prey items to protect fish-eating wildlife (BCMOELP, 1992). Because the EPA Great Lakes criteria were more rigorously developed and differentiate between birds and mammals, these criteria are preferred.

For purposes of the present assessment, the water quality benchmarks considered most appropriate for the Spokane River water are the Washington State acute standard, Nimmi's lowest effect level (0.5 ug/L), the Canadian aquatic life guideline, and the EPA Great Lakes criteria for protecting fish-eating birds (230 pg/L) and mammals.

Sediment

Table 9 shows various benchmarks that have been proposed for total PCBs in freshwater and marine sediments. A number of investigators have identified sediment PCB levels associated with adverse effects on benthic invertebrates, either through assessment of the benthic macroinvertebrate community, bioassays, and/or equilibrium partitioning theory[3]. MacDonald et al. (2000) reviewed the studies of Cubbage et al. (1997), Ingersoll (1996), Persaud et al. (1993), Smith et al. (1996), and Long et al. (1995), listed in Table 9, and derived consensus-based criteria for PCBs and other chemicals. McDonald et al. proposed a threshold effect guideline of 60 ug/Kg and a probable effect guideline of 676 ug/Kg for total PCBs (dry weight).

The National Marine Fisheries Service (NMFS) has derived a tissue concentration of PCBs that is "likely protective against adverse effects in listed salmonid species" (Meador, 2000). NMFS termed this value a residue effect threshold (RET), described under tissue benchmarks below. A sediment total PCB concentration of 225 ug/Kg (dry weight) was calculated as being sufficient to produce the RET, using a biota-sediment accumulation factor of 0.16 and an average sediment total organic carbon (TOC) concentration of 1.5%. The NMFS sediment effects threshold varies with the TOC content. The TOC normalized threshold would be 15,000 ug/Kg TOC (dry weight concentration divided by decimal fraction of percent TOC).

The New York State Department of Environmental Conservation used an equilibrium partitioning approach to derive a total PCB sediment criterion of 1, 400 ug/Kg TOC to protect fish-eating wildlife (NYSDEC, 1998). Their sediment value was based on a water quality criterion of 0.001 ug/L. British Columbia has a somewhat higher wildlife guideline of 2,000 ug/Kg TOC, which is also intended to protect aquatic life (BCMOELP, 1992).

The Spokane River PCB sediment data were compared to the McDonald et al., NMFS, and NYSDEC benchmarks for protecting benthic invertebrates, salmonids, and fish-eating wildlife.

[3] Equilibrium partitioning theory assumes that the partitioning of an organic chemical between sediment organic carbon and interstitial water is at equilibrium and that the concentration in either phase can be predicted using appropriate partition coefficients and the measured concentration in the other phase (EPA, 2000b).

Table 9. Toxicological Benchmarks for Assessing Hazards of Total PCBs to Aquatic Life: SEDIMENT [**Bold** values used in present assessment]

No.	Receptor	Concentration	Units	Type	Effect	Reference
9	benthic invertebrates	**60**	ug/Kg, dry	threshold effect guideline	bioassays/benthic community/ equilibrium partitioning	MacDonald et al., 2000
10	"	**676**	ug/Kg, dry	probable effect guideline		
11	benthic invertebrates	21	ug/Kg, dry	apparent effects threshold	Microtox bioassay	Cubbage et al., 1997
12	benthic invertebrates	32	ug/Kg, dry	threshold effect level	amphipod bioassay	Ingersoll, 1996
13	"	240	ug/Kg, dry	probable effect level	amphipod bioassay	
14	benthic invertebrates	10	ug/Kg, dry	Ontario no effect level	abundance and diversity	Persaud et al., 1993
15	"	70	ug/Kg, dry	Ontario lowest effect level	abundance and diversity	
16	"	530	mg/Kg, OC	Ontario severe effect level	abundance and diversity	
17	benthic invertebrates	34	ug/Kg, dry	Canadian interim threshold effect guideline	bioassays/benthic community/ equilibrium partitioning	Environment Canada, 1995
18	benthic invertebrates	34	ug/Kg, dry	threshold effect level	abundance and diversity	Smith et al., 1996
19	benthic invertebrates	277	ug/Kg, dry	probably effect level	abundance and diversity	
20	benthic invertebrates	23	ug/Kg, dry	NOAA effects range - low	bioassays/benthic community/ equilibrium partitioning	Long et al., 1995
21	"	180	ug/Kg, dry	NOAA effects range - medium		
22	benthic invertebrates	12,000	ug/Kg, OC	Ecology marine standard	apparent effects threshold	173-204 WAC
23	salmonids	**15,000**	ug/Kg, OC	NMFS residue effects threshold	sublethal effects	Meador, 2000
24	wildlife	**1,400**	ug/Kg, OC	NY sediment criterion	reproductive effects	NYSDEC, 1998
25	aquatic life and wildlife	2,000	ug/Kg, OC	British Columbia guideline	reproductive effects	BCMOELP, 1992

No published sediment benchmark values could be located for effects on spiny-rayed fishes (i.e., suckers, bass, perch), but these would likely be higher than the NMFS benchmark for salmonids because spiny-rays are less sensitive to PCBs.

Fish Tissue

Fish tissue benchmarks for total PCBs are shown in Table 10. Body burdens must reach relatively high concentrations in fish and very high concentrations in invertebrates before mortality begins to occur. Salmonids are generally more sensitive than spiny-rayed fishes. The mortality effects levels selected for fish – 3,000 ug/Kg for salmonids and 9,300 ug/Kg for spiny-rays – were the lowest found in the literature.

Table 10. Toxicological Benchmarks for Assessing Hazards of Total PCBs to Aquatic Life: TISSUE [**Bold** values used in present assessment]

No.	Receptor/Media	Concentration	Units	Type	Effect	Reference
26	crayfish / whole body	40	ug/Kg, wet	NOEL	mortality	Sanders & Chandler, 1972
27	macroinvertebrates	**>25,000**	ug/Kg, wet	LOEL	mortality, growth, reproduction	Nimmi, 1996
28	spiny-rayed fishes / tissue	**9,300**	ug/Kg, wet	LOEL	early life stage mortality	TAMS, 2000
29	"	1,900	ug/Kg, wet	NOEL	early life stage mortality	
30	salmonids / whole body	**3,000**	ug/Kg, wet	LOEL	fry mortality	Mac & Seelye, 1981; Berlin et al., 1981
31	salmonids / tissue	**2400**	ug/Kg, lipid	NMFS residue effects threshold	sublethal effects	Meador, 2000
32	fish-eating wildlife / prey	110	ug/Kg, wet	NY fish flesh criterion	reproduction / 1 in 100 cancer risk	Newell et al., 1987
33	fish-eating wildlife / prey	**100**	ug/Kg, wet	British Columbia guideline	maximum to protect wildlife	BCMOELP, 1992

NMFS's RET for salmonids is 2,400 ug/Kg lipid (Meador, 2000). This value was the 10th percentile tissue concentration from 15 studies showing sublethal effects of PCBs on salmonids. The RET is normalized to percent lipid because the higher the lipid content, the higher the proportion of PCBs are associated with lipid and not available to cause toxicity.

Two environmental agencies, NYSDEC (Newell et al., 1987) and the British Columbia Ministry of Environment, Lands, and Parks (BCMOELP, 1992) have proposed similar guidelines of 100 – 110 ug/Kg total PCBs in prey items to protect fish-eating wildlife.

The above-mentioned total PCB benchmarks were used for comparison to the Spokane River fish tissue data. No Observable Effects Levels (NOELs), as shown for crayfish and spiny-rayed fish in Table 10 and in subsequent tables, although useful for some applications, were not used to calculate HQs because the result is not necessarily indicative of or proportional to an effect.

Additional tissue benchmarks are available for PCBs in terms of dioxin TEQs (Table 11). Among the numerous fish species that have been tested, results were found for three species or genera that have been frequently sampled in the Spokane River: yellow perch, sucker, and rainbow trout. Only total PCB data, however, are available for Spokane River yellow perch.

Although the sucker and trout TEQ benchmarks are for the eggs – which also have not been analyzed – the values are lipid-normalized. Therefore, the lipid-normalized whole fish TEQ concentrations for the Spokane were compared to these benchmarks, assuming PCBs have the same affinity for the lipid in eggs as in whole body. The Spokane fish tissue congener data were also compared to the Canadian TEQ guideline of 0.00079 ug/Kg for protection of fish-eating wildlife (CCME, 1999).

Wildlife Diets

EPA recently conducted an extensive assessment of the ecological risk due to PCBs in the Hudson River (TAMS, 2000). As an alternate approach to the generic wildlife benchmarks described above, selected data from the TAMS report were used to estimate the hazard to several fish-eating bird and mammal species that occur in the Spokane River. The TAMS assessment was peer reviewed by a panel of independent scientific experts.

Table 12 shows PCB intake rates selected by TAMS as toxicity reference values for reproduction, survival, and growth in the following Spokane River species: belted kingfisher, great blue heron, bald eagle, otter, and mink. Dietary benchmarks were calculated for both total PCBs and TEQs. As indicated in Table 11, some of the intake values were derived from other species but applied by EPA to these local species, as well as others.

The LOELs for total PCBs in Table 12 were used to calculate HQs for Spokane River wildlife. Mink occur rarely, if at all, in the Spokane River but were included because of their extreme sensitivity to PCBs. The raccoon was not evaluated because its diet is approximately 37% aquatic invertebrates, for which there are little data, and 60% from non-river sources (TAMS, 2000).

Table 11. Toxicological Benchmarks for Assessing Hazards of TEQs* to Aquatic Life: TISSUE
[**Bold** values used in present assessment]

No.	Receptor/Media	Concentration	Units	Type	Effect	Reference
34	yellow perch / tissue	250	ug /Kg, lipid	LC-50	mortality in juveniles	Spitsbergen et al., 1988
35	"	150	ug /Kg, lipid	LOEL	growth in juveniles	
36	"	50	ug /Kg, lipid	NOEL	growth in juveniles	
37	white suckers / eggs	76	ug /Kg, lipid	LC-50	early life stage mortality	Elonen et al., 1998
38	"	**49**	ug /Kg, lipid	LOEL	early life stage mortality	
39	"	34	ug /Kg, lipid	NOEL	early life stage mortality	
40	rainbow trout / eggs	4.3 - 5.0	ug /Kg, lipid	LC-50	early life stage mortality	Zabel & Peterson, 1996;
41	"	**3.2 - 3.3**	ug /Kg, lipid	LOEL	early life stage mortality	Walker & Peterson, 1991;
42	"	3.3	ug /Kg, lipid	NOEL	early life stage mortality	Walker et al., 1992
43	fish-eating birds / eggs	8 - 25	mg /Kg, wet	- -	decreased hatching success	Hoffman et al., 1996
44	fish-eating birds / brain	75 - 300	mg /Kg, wet	- -	lethality	
45	fish-eating wildlife / prey	**0.00079**	ug /Kg, wet	Canadian tissue residue guideline	reproductive effects	CCME, 1999
46	mink / prey	0.0019	ug /Kg, wet	threshold dose	reproductive effects	Tillet et al., 1996

*2,3,7,8-TCDD toxic equivalents

Table 12. Toxicological Benchmarks for Assessing Hazards of Total PCBs and TEQs* to Fish-eating Wildlife: DIETARY INTAKE
[**Bold** values used in present assessment]

	Receptor	Concentration	Units	Type	Effect	Reference
47	Fish-eating birds**	1800***	ug/Kg/day	NOEL	reproduction, survival, growth	TAMS, 2000
48	Fish-eating birds**	**7100*****	ug/Kg/day	LOEL	reproduction, survival, growth	TAMS, 2000
49	Raccoon	230	ug/Kg/day	NOEL	reproduction	TAMS, 2000
50	Raccoon	1500***	ug/Kg/day	LOEL	reproduction	TAMS, 2000
51	Mink and Otter	4	ug/Kg/day	NOEL	reproduction	TAMS, 2000
52	Mink and Otter	**40**	ug/Kg/day	LOEL	reproduction	TAMS, 2000
53	Fish-eating birds**	0.0014***	ug TEQ/Kg/day	NOEL	reproduction, survival, growth	TAMS, 2000
54	Fish-eating birds**	0.014***	ug TEQ/Kg/day	LOEL	reproduction, survival, growth	TAMS, 2000
55	Raccoon	0.001***	ug TEQ/Kg/day	NOEL	reproduction	TAMS, 2000
56	Raccoon	0.01***	ug TEQ/Kg/day	LOEL	reproduction	TAMS, 2000
57	Mink and Otter	0.00008	ug TEQ/Kg/day	NOEL	reproduction	TAMS, 2000
58	Mink and Otter	0.0022	ug TEQ/Kg/day	LOEL	reproduction	TAMS, 2000

*2,3,7,8-TCDD toxic equivalents
**Belted kingfisher, great blue heron, and bald eagle
***This value derived from other species

Hazard Assessment

Table 13 shows the HQs calculated for the Spokane River. A reference to the pertinent benchmark is provided. Details on how the Spokane River data were used in the HQ calculation follow:

1) Kaiser's most recent estimates for total dissolved PCBs in Spokane River water (Table 7) were compared to benchmarks for PCBs in water. Results for the two sampling sites above Kaiser were averaged using half the detection limit. Although the benchmarks are for whole water (dissolved + particulate fractions), at the low concentrations of suspended matter in the Spokane River, the bulk of the PCBs would be expected to be in dissolved or colloidal form. As noted previously, PCB concentrations derived from SPMDs should be considered estimated values.

Table 13. Hazard Quotients for PCBs in Spokane River Water, Sediment, and Tissue

[Based on averaged concentrations and other assumptions described in text. Values > 1 indicate PCB concentrations may be hazardous to aquatic life or wildlife.]

				Hazard Quotient					
Exposure Medium / Receptor / Effect	Benchmark Type	PCB Form	Table / Benchmark	State Line - Trentwood	Trentwood Upriver Dam	Upriver Dam - Monroe St. Dam	Monroe St. Dam 9-Mile Dam	Long Lake	Spokane Arm
Water									
zooplankton	LOEL	total	8/2	0.0001	0.001	0.0007	0.003	no data	no data
aquatic life, acute toxicity	Wash. St. standard	total	8/3	0.00004	0.0003	0.0002	0.0006	no data	no data
aquatic life, acute/chronic toxicity	Canadian guideline	total	8/5	0.07	0.6	0.3	**1.3**	no data	no data
fish-eating birds, reproduction	Great Lakes criterion	total	8/7	0.3	**2.5**	**1.4**	**5.4**	no data	no data
fish-eating mammals, reproduction	Great Lakes criterion	total	8/8	0.9	**7.7**	**4.5**	**17**	no data	no data
Sediment									
benthic invertebrates, abundance/diversity	threshold effect	total	9/9	0.5	**9.8**	**2.5**	insuff. data	0.6	0.4
benthic invertebrates, abundance/diversity	probable effect	total	9/10	0.05	0.9	0.2	insuff. data	0.1	0.04
salmonids, sublethal	NMFS effects threshold	total	9/23	0.1	0.5	0.8	insuff. data	0.1	0.1
wildlife, reproduction	NY criterion	total	9/24	0.9	**5.6**	**8.9**	insuff. data	**1.2**	1.0
Fish Tissue									
macroinvertebrates, mort/growth/reprod.	LOEL	total	10/27	no data	insuff. data	insuff. data	insuff. data	no data	no data
spiny-rayed fishes, mortality	LOEL	total	10/28	0.01	0.05	0.03	0.06	0.02	0.02
salmonids, mortality	LOEL	total	10/30	0.03	0.3	0.1	0.2	0.1	no data
salmonids, sublethal	NMFS effects threshold	total	10/31	0.4	**4.1**	**2.2**	**3.5**	**1.8**	no data
fish-eating wildlife, reproduction (in prey)	BC guideline	total	10/33	1.0	**6.0**	**3.4**	**5.0**	**2.0**	**2.0**
suckers, mortality (in eggs)	LOEL	TEQs	11/38	no data	<0.02	no data	insuff. data	insuff. data	no data
rainbow trout, mortality (in eggs)	LOEL	TEQs	11/41	no data	<0.07	<0.12	insuff. data	insuff. data	no data
fish-eating wildlife, reproduction (in prey)	Canadian guideline	TEQs	11/45	inadeq. data	inadeq. data	inadeq. data	insuff. data	insuff. data	no data
kingfisher, reproduction (dietary intake)	LOEL	total	12/48	0.006	0.03	0.02	0.03	0.01	0.01
great blue heron, reprod. (dietary intake)	LOEL	total	12/48	0.002	0.01	0.01	0.01	0.004	0.004
bald eagle, reproduction (dietary intake)	LOEL	total	12/48	0.002	0.01	0.01	0.01	0.004	0.004
mink, reproduction (dietary intake)	LOEL	total	12/52	0.4	**2.4**	**1.3**	**2.0**	0.8	0.8
otter, reproduction (dietary intake)	LOEL	total	12/52	0.3	**1.8**	1.0	**1.5**	0.6	0.6

2) The sediment total PCB data (Table 5) were averaged by river reach. The few samples collected above the border were included in the State Line to Trentwood data. Non-detects were set at half the detection limit. Average values were used where multiple sediment samples were collected from the same location or for duplicate analyses. Appendix B shows the average sediment values used.

3) For comparison to the total PCB fish tissue benchmarks, whole fish data (Table 1) were used from the State Line to Nine-Mile Dam. Both whole fish and fillet data (Table 2) were used for Long Lake and the Spokane Arm, because only fillets have been analyzed from most species in these areas. Crayfish were not part of this calculation.

4) As with sediment, average fish tissue total PCB concentrations were calculated for each reach (Appendix B). Because no consistent pattern of increasing or decreasing PCB levels has been observed over the past few years, the data from 1993 through 1999 were generally used. In light of the unusually high PCB concentrations reported in 1993 for suckers and trout above Upriver Dam, for suckers above Nine-Mile Dam, and for Long Lake mountain whitefish, these data were not included. Including or not including data from certain years did not have much effect on the conclusions drawn about the PCB hazard.

5) Because there was so little congener data available, both the whole fish and fillet data from 1999 (Table 3) were averaged for HQ calculations based on TEQs (Appendix B). The TEFs proposed by WHO were used (Appendix C). As previously noted, the 1999 congener analysis conducted on Spokane River fish did not quantify the most toxic compounds. Therefore, the detection limit was used for non-detected values, resulting in a conservative, overestimate of the hazard. The data for fish sample number 48-5015 were not used because of unusually high detection limits. The detection limit approach was not extended to a comparison with the very low Canadian wildlife TEQ guideline, because the resulting HQ was unrealistically high.

6) A simplified method was used to calculate HQs based on dietary exposure to individual fish-eating bird and mammal species. The exposure parameters used (body weight, dietary intake, diet composition) are in Appendix D. The calculation was done for the female of the species. It was assumed that the entire diet was composed of Spokane River fish, thus this is a conservative estimate of hazard. Intake of PCBs from water or sediment was not considered. The average fish tissue total PCB concentrations, described above, were used.

State Line to Trentwood (river mile 96.5 – 86.5)

PCB levels in this section of the upper Spokane River are moderate to low and do not represent a significant hazard to aquatic life or fish-eating wildlife.

Trentwood to Upriver Dam (river mile 86.5 – 80.2)

This is the most contaminated reach of the river. Based on average sediment concentrations of total PCBs, the threshold for adverse effects on benthic macroinvertebrates is exceeded by

approximately a factor of 10. Although average sediment PCB concentrations are below the probable effect concentration for benthic invertebrates and the NMFS effects threshold for salmonids, these benchmarks are substantially exceeded within the PCB hotspots behind Upriver Dam. Results of sediment bioassays have shown evidence of toxicity at some of these sites (EILS, 1995; Johnson and Norton, in prep.)

Average tissue concentrations of total PCBs in rainbow trout are approximately four times the NMFS RET for salmonids in this part of the river, suggesting that sublethal adverse effects are likely occurring. It is not clear what affects PCBs are having on the trout populations, but, at a minimum, it represents another stress to these fish, in addition to metals, disease, predation, etc. The available co-planar PCB congener data do not show a significant threat to either salmonids or spiny-rayed fishes, here or in the next reach downstream, the only two areas for which there are some congener data on tissue.

The limited data available on PCB concentrations in the water column point to a hazard for fish-eating wildlife, particularly mammals. When considering wildlife dietary intake the calculations based on fish tissue samples indicate it is unlikely that birds feeding on fish within this reach would be adversely affected by PCBs. Some impaired reproduction of fish-eating mammals could, however, potentially occur if they were dependent on this resource. Based on average fish tissue concentrations, HQs exceeded the BC wildlife guideline by a factor of 6 and the dietary intake HQ for otter and mink by approximately a factor 2.

Upriver Dam to Monroe Street Dam (river mile 80.2 – 74.2)

The hazards to benthic macroinvertebrates, salmonids, and wildlife reproduction extend down into this reach, although to a lesser extent. Where fish tissue HQs are exceeded for salmonids and fish-eating mammals, it is only by factors of slightly more than 1 and 3, compared to 2 and 6 above Upriver Dam, respectively. As with Trentwood to Upriver Dam, contaminated sediments occur in scattered deposits of fine material, so the overall hazard to benthic invertebrates is more limited in actual extent than the HQs indicate.

Monroe Street Dam to Nine-Mile Dam (river mile 74.2 – 58.1)

The PCB concentrations in the sediments of this reach are poorly known. However, most of this area is also non-depositional (except behind Nine-Mile Dam) and its two major tributaries, Latah Creek and Deep Creek, contribute most of the sediment load. Neither creek is known to be a significant PCB source.

The PCB concentrations that have been measured in fish tissue suggest the hazard to salmonids and fish-eating mammals in the Monroe Street Dam to Nine-Mile Dam reach may be slightly greater than further upstream above Monroe Street Dam, but less than above Upriver Dam. Although the data on PCBs in water support a concern about fish-eating wildlife, the data are limited and may overstate the hazard.

Long Lake (river mile 58.1 – 33.9)

In Long Lake, HQs are close to or much less than 1.0. In the worst-case scenario, only minor adverse effects are likely to be occurring in salmonids or in fish-eating wildlife.

Spokane Arm (river mile 29.3 – 0)

HQs are similar to or lower than in Long Lake, suggesting a low hazard due to PCB concentrations in this part of the river.

Uncertainty

A number of factors contribute uncertainty to this PCB hazard assessment, mostly stemming from the fact that past surveys in the Spokane have largely focused on human health concerns and that recent surveys (i.e., since 1994) have been limited to the upper river. Chief among these factors are:

- Limited amount of recent data on PCB concentrations in whole fish
- Lack of data on PCB concentrations in fish eggs or in wildlife tissues
- Recent fish tissue data limited to three species
- No recent fish tissue data downstream of Nine-Mile Dam
- Size range of fish analyzed skewed toward larger individuals which may have higher PCB concentrations
- Limited nature of the PCB congener data

Additional sources of uncertainty include the following:

- Lack of data or limited data for certain reaches, such as Monroe Street Dam to Nine-Mile Dam (sediment data), Long Lake Dam to Little Falls Dam (no data), and the Spokane Arm (sediment data)
- Limited nature of the PCB data on river water
- Extrapolation of laboratory-derived benchmarks to the natural environment
- Interspecies variation in PCB sensitivity

If field sampling were conducted to fill some of the above-mentioned data gaps, the most likely outcome would be no significant changes to or a lowering of the ecological hazard attributable to PCBs. This conclusion is based on: 1) the present assessment's use of whole fish data on large individuals, skewing the average PCB concentration upward; 2) the more highly contaminated fish samples having been analyzed for PCB congeners and the levels being relatively low in terms of TEQs; and 3) the downstream trend toward lower PCB concentrations in the sediments and the non-depositional character of most of the river above Nine-Mile Dam.

Finally, simple exceedances of certain benchmarks often do not alone fully demonstrate that measurable adverse impacts are occurring, thus a weight of evidence approach is useful when predicting sublethal impacts: for example, incorporating recent biological surveys conducted by the USGS or sediment bioassays conducted by Ecology. There remains, however, insufficient data to establish a quantifiable link between PCB concentrations in the river and impacts to resident invertebrate, fish, and wildlife at the individual or population level. Also, for a number of endpoints, the high metals levels in the river make it difficult to isolate what effects may be due to PCBs. The potential for aggregate chemical effects is significant but not well understood.

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Conclusions

Based on the available data and the benchmarks used in this assessment, the primary ecological hazards identified for PCBs in the Spokane River are:

1) Possible adverse effects on the sustainability of salmonid populations and fish-eating mammals, primarily in the reach between approximately Trentwood and Nine-Mile Dam.

2) Possible adverse effects on benthic invertebrates in the Trentwood to Monroe Street Dam reach in areas where PCBs have been concentrated in fine-grained sediments such as behind Upriver Dam.

The effects on salmonids would be expected to be sublethal. Sufficient information is not available to determine how this may be affecting the health of the trout or whitefish populations. Spiny-rayed species are less likely to be affected. Sensitive fish-eating mammals would be expected to have some reduced reproductive success, but only if they are highly dependent on fish from this reach as the major part of their diet. Because of the patchy distribution of fine sediments, toxicity to benthic invertebrates is probably confined to localized deposits of contaminated material.

The ecological hazard due to the PCB levels in Long Lake and in the Spokane Arm is low.

Fish-eating birds do not appear to be at risk in any part of the river.

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Appendices

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Appendix A. Recent Ecology Data on Total PCBs in Washington State Freshwater Fish, Excluding the Spokane River (single composite samples; ug/Kg, wet weight)

Year	Location	Species	Tissue	Total PCBs	% Lipid	Reference
1992	Lake Chelan	Largescale sucker	Whole	17	1.79	1
1992	Lake Chelan	Rainbow trout	Fillet	15	0.13	1
1992	Lake Chelan	Kokanee	Fillet	12	0.54	1
1992	Crab Creek	Largescale sucker	Whole	47	2.36	1
1992	Crab Creek	Mountain whitefish	Fillet	30	2.47	1
1992	Walla Walla River	Largescale sucker	Whole	138	1.94	1
1992	Walla Walla River	White crappie	Fillet	40 U	0.15	1
1992	Yakima River	Largescale sucker	Whole	154	5.18	1
1992	Yakima River	Smallmouth bass	Fillet	12	0.06	1
1992	Mercer Slough	Largescale sucker	Whole	379	3.66	1
1992	Mercer Slough	Rainbow trout	Fillet	51	0.05	1
1992	Lake River	Largescale sucker	Whole	199	4.47	1
1993	Walla Walla River	Largescale sucker	Whole	122	4.98	2
1993	Walla Walla River	Carp	Fillet	300	3.91	2
1993	Walla Walla River	Steelhead	Fillet	555 U	7.01	2
1993	Nooksack River	Largescale sucker	Whole	555 U	4.56	2
1993	Fishtrap Creek	Rainbow trout	Fillet	555 U	3.89	2
1993	Wenatchee River	Largescale sucker	Whole	286	5.08	2
1993	Mission Creek	Rainbow trout	Fillet	555 U	1.84	2
1993	Chehalis River	Largescale sucker	Whole	84	3.98	2
1993	Chehalis River	Mountain whitefish	Fillet	143	5.72	2
1993	Salmon Creek	Largemouth bass	Fillet	555 U	2.82	2
1993	Vancouver Lake	Largemouth bass	Fillet	110	3.85	2
1993	Vancouver Lake	Carp	Whole	280	7.80	2
1994	Lake Sacajawea	Largescale sucker	Whole	62	7.2	3
1994	Lake Sacajawea	Channel catfish	Fillet	61	4.9	3
1994	Palouse River	Largescale sucker	Whole	31	2.6	3
1994	Palouse River	Squawfish	Fillet	11	1.5	3
1994	Okanogan River	Largescale sucker	Whole	64	7.2	3
1994	Okanogan River	Carp	Fillet	45	9.1	3
1994	Lake Chelan	Largescale sucker	Whole	69	4.7	3
1994	Lake Chelan	Kokanee	Fillet	99	1.6	3
1994	Lake Chelan	Rainbow trout	Fillet	80	1.5	3
1994	Lake Chelan	Smallmouth bass	Fillet	16	3.9	3
1994	Entiat River	Largescale sucker	Whole	62	4.7	3
1994	Soleduck River	Mountain whitefish	Fillet	60 U	6.5	3

1995	Canal Lake	Largemouth bass	Fillet	39 U	1.07	4
1995	Canal Lake	Yellow perch	Fillet	78 U	0.56	4
1995	Redrock Lake	Largemouth bass	Fillet	39 U	0.85	4
1995	Redrock Lake	Largemouth bass	Fillet	39 U	1.75	4
1995	Royal Lake	Smallmouth bass	Fillet	59 U	1.99	4
1995	Royal Lake	Carp	Whole	39 U	10.62	4
1995	Scooteney Reservoir	Smallmouth bass	Fillet	39 U	0.71	4
1995	Scooteney Reservoir	Smallmouth bass	Fillet	39 U	1.73	4
1995	Scooteney Reservoir	Largemouth bass	Fillet	39 U	0.68	4
1995	Scooteney Reservoir	Largemouth bass	Fillet	39 U	1.88	4
1995	Scooteney Reservoir	Carp	Whole	39 U	7.69	4
1995	Clear Creek	Cutthroat trout	Fillet	46	1.63	4
1995	Cowlitz River	Cutthroat trout	Fillet	84	3.00	4
1995	Cowlitz River	Mountain whitefish	Fillet	47	5.99	4
1995	Cowlitz River	Mountain whitefish	Fillet	60	5.78	4
1995	Cowlitz River	Largescale sucker	Whole	96	2.64	4
1995	Yakima River	Smallmouth bass	Fillet	25	0.40	4
1995	Yakima River	Carp	Fillet	135	0.82	4
1995	Yakima River	Largescale sucker	Whole	279	2.91	4
1995	Cowiche Creek	Rainbow trout	Fillet	96	2.02	4
1997	Douglas Creek	Rainbow trout	Fillet	19 U	4.3	5
1998	Lake Whatcom	Kokanee	Fillet	9.5	4.7	6
1998	Lake Whatcom	Kokanee	Fillet	7.6	4.0	6
1998	Lake Whatcom	Smallmouth bass	Fillet	3.4	1.1	6
1998	Lake Whatcom	Smallmouth bass	Fillet	9.0	1.8	6
1998	Lake Whatcom	Longnose sucker	Whole	9.5	4.9	6
1998	Lake Whatcom	Sculpin	Whole	36	5.5	6
1995	Lake Osoyoos	Largescale sucker	Whole	24	4.3	7
1995	Lake Osoyoos	Largescale sucker	Whole	66	4.3	7
1995	Lake Osoyoos	Smallmouth bass	Fillet	40 U	1.04	7
1992	Potholes Reservoir	Lake whitefish	Fillet	73 U	7.3	8
1992	Potholes Reservoir	Largemouth bass	Fillet	69 U	0.3	8
1992	Potholes Reservoir	Largescale sucker	Whole	71 U	8.6	8
1992	Roses Lake	Brown bullhead	Fillet	97 U	0.8	8
1992	Roses Lake	Rainbow trout	Fillet	67 U	0.9	8
1992	Roses Lake	Brown bullhead	Whole	74 U	1.5	8
1992	Sammish Lake	Brown bullhead	Fillet	77 U	0.5	8
1992	Sammish Lake	Largemouth bass	Fillet	110 U	0.4	8
1992	Sammish Lake	Largescale sucker	Whole	169	4.5	8
1992	Ward Lake	Largemouth bass	Fillet	99 U	0.1	8
1992	Ward Lake	Rainbow trout	Fillet	8	1.0	8

1999	Ward Lake	Largemouth bass	Fillet	19.1	0.1	9
1999	Ward Lake	Rainbow trout	Fillet	13.6	2.3	9
1999	Ward Lake	Cutthroat trout	Fillet	13.3	2.2	9
1999	Ward Lake	Kokanee	Fillet	16.4	9.4	9
1999	Elwha River	Rainbow trout	Fillet	17.6	1.4	9
1999	Elwha River	Rainbow trout	Fillet	8.8	0.5	9
1999	Elwha River	Rainbow trout	Fillet	13.0	1.2	9

U = not detected at or above reported value

References:

1 = Davis & Johnson (1994)
2 = Davis et al. (1995)
3 = Davis & Serdar (1996)
4 = Davis et al. (1998)
5 = Johnson (1998)
6 = Serdar et al. (1999)
7 = Serdar et al. (1998)
8 = Serdar et al. (1994)
9 = Serdar (1999)

Appendix B. Average PCB Concentrations in Fish Tissue, Sediment, and Water Used to Calculate Hazard Quotients for the Spokane River

Category	Units	State Line - Trentwood	Trentwood Upriver Dam	Upriver Dam - Monroe St. Dam
Total PCBs in Spiny-Rayed Fish	ug/Kg, wet	123	445	254
Total PCBs in Salmonids	ug/Kg, wet	77	755	380
Total PCBs in Salmonids	ug/Kg, lipid	928	9805	5398
Total PCBs in Fish Tissue	ug/Kg, wet	100	600	338
Dioxin TEQs in Suckers	ug/Kg, lipid	no data	0.23	0.40
Dioxin TEQs in Rainbow Trout	ug/Kg, lipid	no data	0.86	no data
Dioxin TEQs in Fish Tissue	ug/Kg, lipid	no data	0.54	0.40
Total PCBs in Sediment	ug/Kg, dry	31	585	148
Total PCBs in Sediment	ug/Kg TOC	1,300	7,795	12,463
Total PCBs in Water	ng/L	0.07	0.57	0.33

Category	Units	Monroe St. Dam 9-Mile Dam	Long Lake	Spokane Arm
Total PCBs in Spiny-Rayed Fish	ug/Kg, wet	354	218	198
Total PCBs in Salmonids	ug/Kg, wet	576	155	no data
Total PCBs in Salmonids	ug/Kg, lipid	8407	4354	no data
Total PCBs in Fish Tissue	ug/Kg, wet	502	200	198
Dioxin TEQs in Suckers	ug/Kg, lipid	no data	no data	no data
Dioxin TEQs in Rainbow Trout	ug/Kg, lipid	no data	no data	no data
Dioxin TEQs in Fish Tissue	ug/Kg, lipid	no data	no data	no data
Total PCBs in Sediment	ug/Kg, dry	9.1	36	25
Total PCBs in Sediment	ug/Kg TOC	506	1,735	1,361
Total PCBs in Water	ng/L	1.3	no data	no data

Appendix C. WHO Toxic Equivalency Factors (TEFs) for Fish, Birds, and Mammals [van den Berg et al., 1998]

Congener	Fish	Birds	Mammals
Non-ortho PCBs			
PCB-81	0.0005	0.1	0.0001
PCB-77	0.0001	0.05	0.0001
PCB-126	0.005	0.1	0.1
PCB-169	0.00005	0.001	0.01
Mono-ortho PCBs			
PCB-105	<0.000005	0.001	0.0001
PCB-114	<0.000005	0.001	0.0005
PCB-118	<0.000005	0.00001	0.0001
PCB-123	<0.000005	0.00001	0.0001
PCB-156	<0.000005	0.001	0.0005
PCB-157	<0.000005	0.001	0.0005
PCB-167	<0.000005	0.00001	0.00001
PCB-189	<0.000005	0.00001	0.0001

Appendix D. Exposure Parameters Used for Wildlife Dietary Intake Calculations [TAMS, 2000]

Common Name	Belted kingfisher	Great blue heron	Bald eagle	Otter	Mink
Genus Species	*Ceryle alcyon*	*Ardea herodius*	*Haliaeetus leucocephalus*	*Lutra canadensis*	*Mustela vision*
Sex	female	female	female	female	female
Body Weight (Kg)	0.147	2.2	5.1	7.3	0.83
Total Daily Intake (Kg/day, wet)	0.058	0.35	0.65	0.90	0.13
Diet Composition:					
Fish	78%	98%	100%	100%	34%
Aquatic Invertebrates	22%	1%	0%	0%	16%
Non-river	0%	0%	0%	0%	50%